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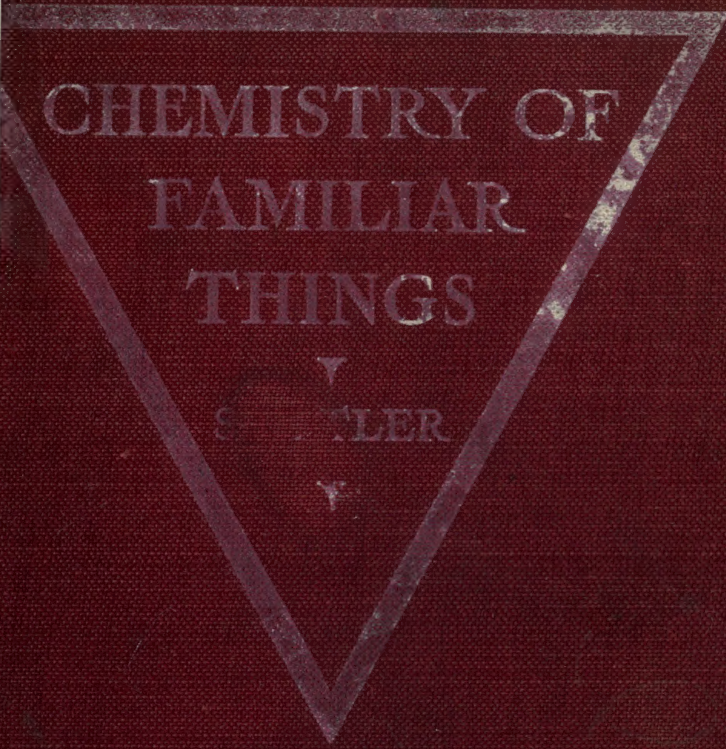

CHEMISTRY OF FAMILIAR THINGS

SADTLER

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Chemical Products being Made by Nature's Insect Artisans.

Drawn by A. H. Sadtler.

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CHEMISTRY OF FAMILIAR THINGS

BY

SAMUEL SCHMUCKER SADTLER, S.B.

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SECOND EDITION REVISED

154922
6/5/20

PHILADELPHIA AND LONDON
J. B. LIPPINCOTT COMPANY

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AT THE WASHINGTON SQUARE PRESS
PHILADELPHIA, U. S. A.

TO MY WIFE

PREFACE

This book has been written because of a demand for an insight into chemistry by those whose training or whose reading has been directed in other channels. Chemistry has been regarded as a difficult and confusing study by beginners; yet they seem to grant that it must be a very absorbing and interesting pursuit to the chemist himself. If this be true it is only necessary for the chemist to present the subject with its natural attractions in a non-technical way. He may then both instruct and interest those who would like to extend their courses of reading to learn more about natural phenomena and to familiarize themselves with things in Nature and the Arts.

The writer has dwelt at some length upon the chemistry of such subjects as Air, Water, Metals, Rocks, Soil, Food, Textiles, Chemical Evolution and Physiological Chemistry, and has only introduced enough elementary chemistry in the first chapter to enable the reader to better understand and appreciate the sequel.

The writer offers this book for perusal by those who are interested in scientific matters and for careful study by those who desire an exposition of every-day practical chemistry. It is probable that short courses in chemistry can render more concrete results and be more productive of real benefit by the use of such a book as this rather than a text-book of the more usual kind.

The author wishes hereby to acknowledge his indebtedness to Dr. S. P. Sadtler and Mr. C. O. Bond for suggestions made use of in the manuscript and proofs and to his sister, Alice H. Sadtler, for her interest in making original sketches for illustrations. For kindness in furnishing photographs for illustrations Prof. Albert Sauveur, Dr. E. F. Roeber, Prof. Louis V. Pirsson, The Lowell Observatory and the Research Corporation are also thanked by the writer.

S. S. SADTLER.

CHESTNUT HILL, PHILADELPHIA
October 5, 1914.

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CHEMISTRY OF FAMILIAR THINGS

INTRODUCTION

Chemistry has been looked upon as a difficult branch of science, but one finds it no more difficult than any of the other branches of exact science. Any experimental science requires a large amount of study and practice to enable the worker to excel sufficiently to be valuable to his fellows. It certainly is true, however, that, while vast service has been performed by chemistry in adding to the satisfaction of civilized living, chemistry has not appealed to very many people who were not themselves chemists.

There seem now, however, to be signs of an awakening as to the interesting possibility of science considered broadly, and there is no doubt in the mind of the writer that chemistry can furnish interesting subject-matter for general consideration. Then, too, an interest in one subject will create interest in another. Interest in biology will easily and properly spread to interest in chemistry, and *vice versa.* One cannot take up the study of agriculture without giving consideration to chemistry.

How many chemical substances have been elaborated by insects! We have been calmly taking the results of their patient work without much appreciation. For instance, consider the honey-bee. Any one would be interested in the bee if he read John Burroughs' description of the honey-bee. One thing that impressed the writer was that we had a wonderful little chemist in the bee. He wanted a substance to make his storehouse and partition his home. Wasps use mud, hornets make a crude paper, but the bee was by far the most enterprising and evolved a perfect plastic substance in ordinary *beeswax,* one that has never been duplicated by man. We know, too, it is always made up to standard in composition. Then we have the *honey,* which is made out of all kinds of natural sugars, but the bee converts them all into honey, which is practically lævulose, a delicate and easily digestible form of sugar. Commerce and industry have long been indebted to the lac insect for the valuable substance *shellac,* which is the toughest resin we have. The beautiful color *cochineal* is the specialty of another race of insects bearing that name. The bright red color carmine is the aluminum compound of the natural color. We have also made use of tannin, a variety of which is produced in plants by the sting of insects.

We have the vast and innumerable elaboration of chemicals from the fungi and bacteria, such as alcohol and carbon dioxide from yeasts; acetic acid, lactic acid, and other substances from bacteria; each organism producing its kind and quota of chemical substances so long as the organism is properly nourished and is maintained at a suitable temperature. Similarly, all other chemical processes need the proper raw materials and require certain limits of temperature for the best results.

In the realm of fibres, we have the spiders and silkworms who spin nothing but the finest filaments. These, human ingenuity can only approach in perfection. We make artificial silk out of cotton, but it is only a poor substitute for the real article, and we have absolutely no way of making anything with the delicacy of the natural fibre from the ordinary spider, who seems to have first made nests or cocoons, and later discovered the possibilities, from a practical and artistic standpoint, of making webs.

In the field of inorganic chemistry we have not noticed so much activity, but mention might be made of the wonderful *coral formations* (composed of carbonate of lime) which have caused land to rise above the water in tropical lands. Much of this lime, or maybe all of it, has been leached away from exposed limestone on hillsides by the atmosphere and carried to the ocean, whence it has been returned to land again by the coral insect. The iron deposits known as *bog iron* ore are the deposits of bacteria which are supposed to be nourished by iron which on oxidation supplies these queer forms of life with the necessary energy, and collects the iron in masses for possible future use by man.

In the plant world we find the production of substances of definite chemical composition so widespread that they become matters of the greatest economic importance. This refers to the essential development common to all plants, such as the production of carbohydrates, protein, and oils in the seeds, which are designed to nourish the young plant just as these same classes of substances do animals, and also to the special and apparently superabundant store of substances that seem to exceed the requirements of the plant for ordinary growth.

We have the characteristic *vegetable oils*, such as olive oil, linseed oil, cottonseed oil, cacao butter, and peanut oil, which undoubtedly have a service to perform by supplying energy and tissue to the young plants, but are in such great supply that they are of the greatest value to man for food and technical use. The *essential oils* and *resins* have some natural function, such as rushing to wounded places in the plant and forming a gummy mass that acts as a plaster to restrain the wasteful flow of aqueous sap or plant blood, which comes when the bark is cut. These essential oils or oleoresins (oil and resin) supply us with turpentine and rosin, camphor oil and camphor.

Rubber is closely related to the essential oils, and the rubber latex serves as a healing salve as do the oleoresins. We are also supplied with *alkaloids,* such as morphine, strychnine, and quinine, by plants. We are not sure just what they do for the plants, but they seem potent enough, many of them, to be effective for some purpose. They may be catalytic[1] substances that induce the formation of the plant proteins from nitrates, etc. They can hardly be the decomposition products of the proteins, as the characters of these substances are known to us. These manifestations of chemistry in nature are given to show how real and concrete is the science of chemistry.

It might be thought that enough chemical substances were produced in nature so that men did not have to make any. Even when primitive man was satisfied with natural foods and uncolored fabrics made of skin, etc., he felt the need of tools stronger than wood and more readily shaped than stone, so the manufacture of *metals* from the ores was begun. This was a crude smelting operation, and was probably carried out by heating the ores with some form of carbon like charcoal and with limestone, with an air-blast to intensify the heat. Dye colors were made from plants, such as alizarin from madder root, indigo from the *Indigofera tinctoria,* and many other colors from roots and berries. Natural earths, such as whiting, clay, gypsum, ochres, powdered barks, roots and leaves were also used before chemicals were made.

Little do people see in the changes occurring about them anything that suggests the name of *Chemistry.* The average person is almost unaware of this important line of thought and investigation. The signs of the times now seem to point, however, to the popular possession of a desire for fundamental and accurate information.

---

[1] See definition, p. 314.

Exact knowledge is becoming the only kind that will count with both men and women in the near future. The foregoing does not seem like a dubious prophecy when those who are able to do so note the changes made in half a generation. Fifteen or twenty years ago experts were few; now they are found in all pursuits. I am, therefore, strongly of the belief that it will profit men and women generally to know accurately at least a little chemistry,—at least the little that this book will afford. The day is not far distant when the average business man will know that pure sand, silex, and quartz are all silica; that soda, soda crystals, soda ash, etc., are all forms of sodium carbonate; that Venetian red, rouge, and Indian red are essentially iron oxides; that Glauber's salt is sodium sulphate; that Epsom salt is magnesium sulphate; that cream of tartar is acid potassium tartrate and tartar emetic is potassium antimony tartrate; and so on down the list. It will likewise be found that it will be easier and better to call chemical substances by their scientific names.

After we grapple with a definition of chemistry and find its true place, we will see if there is not much of interest in a subject which treats of the composition of the things about us.

CHAPTER I

BRIEF CHEMICAL OUTLINE

Exact science may be considered as being composed of four great divisions:

1. Astronomy and mathematics.

2. The natural or descriptive sciences, such as geology, botany and zoology.

3. That branch which studies matter in motion,—physics.

4. That branch which studies the composition of matter,—chemistry.

Physics and chemistry may be briefly contrasted. Some changes to which matter is subjected are physical and others chemical. In the case of physical changes the composition of matter is not altered; for instance, when water is heated until steam is evolved. Steam looks very different from water, but there is no alteration in composition in effecting this change. The action of heat merely lessens the mutual attraction of the particles until finally, at the point at which steam is evolved, they repel each other rather than attract, as they did while in the state of water. An example of a chemical change is the burning of gas or coal to carbon dioxide and water, or burning hydrogen in oxygen with formation of water.

If substances in nature are analyzed or subjected to processes of decomposition, they can often be simplified, and the substances that cannot be chemically simplified are known as *elements;* for instance, sodium chloride can be split up into sodium and chlorine, but we are absolutely unable to make simpler substances out of sodium or chlorine. Elements in a chemical sense are considered as ultimate forms of matter. Their identity is clearly established and they enter into combination with each other, but are obtainable again with their original appearances and characteristics.

The simplest forms of matter are therefore known as elements. There are really only a few of these elements that compose the earth's mass that are in abundance. Oxygen and silica comprise about three-fourths of the entire solid crust of the globe. Seven other elements—aluminum, iron, calcium, magnesium, sodium, potassium, and hydrogen—with the two first mentioned, constitute ninety-nine per cent. of the entire quantity, leaving only one per cent. for about sixty-six of the remaining elements. Dr. F. W. Clarke gives the following estimated composition of the earth's crust, including sea and atmosphere:

Oxygen (O)	49.98 per cent.	Titanium (Ti)	0.30 per cent.
Silicon (Si)	25.30 per cent.	Carbon (C)	0.21 per cent.
Aluminum (Al)	7.26 per cent.	Chlorine (Cl)	0.15 per cent.
Iron (Fe)	5.08 per cent.	Phosphorus (P)	0.09 per cent.
Calcium (Ca)	3.51 per cent.	Manganese (Mn)	0.07 per cent.
Magnesium (Mg)	2 50 per cent.	Sulphur (S)	0.04 per cent.
Sodium (Na)	2.28 per cent.	Barium (Ba)	0.03 per cent.
Potassium (K)	2.22 per cent.	Nitrogen (N)	0.02 per cent.
Hydrogen (H)	0.94 per cent.	Chromium (Cr)	0.01 per cent.
		Total	99.99 per cent.

No matter what forces are brought to bear upon these substances, they are not further simplified chemically. Physically (mechanically) pieces of any one element, such as iron, may be comminuted until the particles are impalpably fine, and at the limit of subdivision of which we can conceive we would have the molecules. However, every molecule is theoretically capable of chemical separation into parts, called atoms, of which there are generally two.

Chemical affinity is the attraction or force which binds atoms together to form molecules and causes interchanges among them when dissimilar molecules are brought in contact. Two atoms of the same kind unite, or are found in nature united, to form simple molecules. Atoms of dissimilar character also unite to form compound molecules,[1] which, of course, are no longer elements. If for any reason an atom is uncombined, due to electric action, the influence of radium, etc., it is much more active chemically than when in the molecular condition. At the instant that chlorine, hydrogen, or oxygen, for example, are liberated by electrolysis, they are said to be in the *nascent state* and will form new combinations that they would not form in the molecular state.

---

[1] Simple atoms uniting to form molecules $H + H = H_2$ (hydrogen gas). Dissimilar atoms uniting to form molecules $H + H + O = H_2O$ (water). As atoms do not ordinarily exist alone, they are not usually treated in carefully written chemical formulas, thus, the symbol for free hydrogen is H_2, not H.

All the elements have abbreviations used in writing equations. They are not always the first letters or abbreviations of the English words; some are taken from the Latin, as many of the early chemical or alchemical works were written in Latin; thus, the *symbol* for sodium is Na, a contraction of Natrium, the Latin name for the metal.

Equations are more or less graphic ways of indicating that substances interacting produce one or more other substances. Thus, hydrochloric acid and sodium hydroxide interacting produce sodium chloride plus water ($HCl + NaOH = NaCl + H_2O$). Subscript and prefixed numerals in formulas are, of course, simple multipliers.

The atom may be, and probably is, complex, but the old hypothesis works admirably as yet, for we do not know how the atom is constituted, although it is thought by some to be made up of ethereal vibrations, and, if so, matter is nothing but force or energy.

Hydrogen (a colorless gas) unites with chlorine (a greenish-yellow gas) to form a colorless gas, which is called hydrogen chloride or hydrochloric acid gas ($H_2 + Cl_2 = 2HCl$).

Sulphur (a yellow solid) unites with (or burns with) oxygen to form sulphur dioxide, a colorless gas ($S_2 + 2O_2 = 2SO_2$).

These last two products, when in contact with water, are sour to the taste and are called *acids.*

If the metal sodium be put into water, there is quite a disturbance, even with a very small piece. A reaction ensues which develops heat. Hydrogen gas is given off and the water becomes alkaline from the formation of sodium hydroxide, which is a *base.* ($Na_2 + 2H_2O = 2NaOH + H_2$.)

A base is the opposite of an acid. Bases and acids neutralize each other, with evolution of heat, to form salts. It is not very safe or pleasant to have to taste a mixture to find out whether an acid is present. It has been known for some time, however, that certain organic substances have one color with acids and another with bases or alkalies. For instance, most red vegetable colors turn blue or green with alkalies. Cranberry juice is naturally red, but if an alkali be added it becomes green; so do beets, and a red vegetable substance known as *litmus,* when purified, is colored red with acids and blue with alkalies. It is generally sold in drug stores as *litmus test paper,* and serves as an *indicator* for acids and alkalies.

In the footnote [2] are some examples of the action of acids and bases or alkalies. Bases will generally be called alkalies hereafter, as they are better known by that name. The class of substances known as salts must not be confused with common salt or table salt. This substance is only a typical salt, but was the first known, so it gave the name to the class of similar substances known as salts.

The practical side of this subject is one of daily importance in the home, the factory, and on the farm. In the home people have not been accustomed to the use of indicators, but they could be used to advantage. To be sure that a water is softened with washing soda an indicator, such as litmus paper, can be used. Washing soda would be added to the water until red litmus was just turned blue. The water would then be soft and very slightly alkaline, enough to about neutralize the slight acidity due to the perspiration acids of the clothes. In the factory and works the use of indicators is quite prevalent, especially in large works. In many small

---

[2] Acid		Alkali		Salt		
Hydrochloric acid		Sodium hydroxide		Sodium chloride		Water
HCl	+	$NaOH$	=	$NaCl$	+	H_2O
Sulphuric acid		Potassium hydroxide		Potassium sulphate		Water
H_2SO_4	+	$2KOH$	=	K_2SO_4	+	$2H_2O$

A slightly different example is where instead of an hydroxide we use a carbonate. Instead of getting water alone in the equation, carbon dioxide is also obtained, thus:

$$2HCl + Na_2CO_3 = 2NaCl + H_2O + CO_2.$$

works they could be used to advantage where they are not used now. A leather manufacturer could tell whether his skins and leather at various stages were acid or alkaline. A dyer could judge of the condition of his dye vats. The soap maker could tell when his soap was neutral. On the farm or in the vegetable garden, litmus paper can be used to determine whether or not the soil is acid. If the soil turns moistened blue litmus red, it is acid, and air-slaked lime must be used to neutralize it. Most grains and vegetables grow best in neutral or slightly alkaline soil, while weeds thrive in an acid soil. Grass grows in acid soil—less weeds.

Tests [illegible]

Inorganic acids and alkalies unite to form *salts*. Organic acids unite with alkalies to form *soaps*.[3]

These soaps when pure are neutral to suitable indicators, and *phenolphthalein* in alcohol solution is used in this case rather than litmus. They respond to the test for organic material, as the organic matter burns off when sufficiently heated and leaves an inorganic residue which is always a carbonate (a form of alkali, as we have seen). It is called a mild alkali or a carbonated alkali and it turns red litmus blue. Soaps will be treated later in detail (p. 262).

As this earth was formed by a process that brought it through a state of being a molten mass at a white heat, there could not have existed plant or animal life until relatively recently, when it had cooled off at the surface. Possibly for this reason and because of its greater simplicity, inorganic chemistry was studied first and has first place in all discussions of chemistry that are complete in their scope. *Inorganic chemistry* is essentially mineral chemistry. Most of the inorganic elements usually occur combined in nature. Oxygen occurs uncombined in the air, although mixed with nitrogen. Sulphur occurs free in a few places because of volcanic or similar action. In the cases of the metals, only a few are found in the free state, such as copper (in a few localities), and the so-called noble metals—silver, gold, and platinum—are quite apt to be found in the free state, as they are not very subject to atmospheric influences.

---

[3] Oleic acid + sodium hydroxide (NaOH) = sodium oleate (a soap) + water. Stearic acid + potassium hydroxide = potassium stearate + water.

Organic chemistry is the study of the composition, properties, and changes undergone in substances of animal or vegetable origin. Organic chemistry is essentially the study of the *compounds of carbon.* They are composed largely of compounds of carbon and hydrogen, with or without other non-metallic substances, such as oxygen, nitrogen, chlorine, sulphur, etc., and only occasionally a metal may be in combination.

One of the early lessons we had at school was that there were three great divisions of matter,—animal, vegetable, and mineral. We might combine this classification with a simple chemical one:

$$\left.\begin{array}{l}\text{Animal}\\ \text{Vegetable}\end{array}\right\}\text{Organic}\qquad\qquad \text{Mineral}\left\{\begin{array}{c}\text{Non-metals}\\ \text{Metals}\end{array}\right\}\text{Inorganic}$$

Organic substances can generally be distinguished from inorganic ones by means of heat in the presence of air at a burning temperature. Organic substances are consumed, while nearly all inorganic ones are not. Elements like mercury, arsenic, and chlorine, or compounds like carbon dioxide, ammonia, and sulphur dioxide, are a few of the inorganic substances that are likely to pass off when decomposable substances are subjected to burning conditions, because of their volatility. Nearly all organic substances leave some *ash,* or mineral residue, when burned. Plants and animals cannot grow without mineral matter, such as potassium salts, phosphates, and ammonium salts (or nitrates). They need all three, and all complete fertilizers have all three substances or what will produce them. Therefore some mineral matter will remain on burning vegetables, meat, or other organic tissues, but they are essentially consumed.

There are many chemical substances that cannot be treated here, especially organic substances, of which there are a vast number, and they are very complex in their constitution in many cases. Examples of some simple organic substances where there is no admixture with one or more other substances, are ethyl (grain) alcohol, glycerin, starch, and sugar. Examples of organic materials that are mixtures of several simple organic substances are petroleum oils, vegetable and animal oils, woody tissue, fibres of silk and wool, flour, meat, and other animal and vegetable food materials. Included in organic substances are such general classes as hydrocarbons, as in petroleum; alcohols, such as ordinary ethyl alcohol and wood alcohol; phenols, such as carbolic acid and thymol; aldehydes, such as formaldehyde; acids, such as oleic or benzoic; ethers, such as ordinary ether, used for anæsthesia; esters, such as the delicate flavoring in fruits and wines; carbohydrates, such as glucose and sugar; organic bases, such as pyridine, from which many alkaloids are derived; proteins, such as are found in all flesh and vegetables.

Besides the formation of salts and soaps, probably the most important reactions of a very general nature are *oxidation* and the opposite operation of *reduction.*

On oxidation a substance is affected by the reaction with oxygen or its equivalent. In the case of reduction, the substance is affected by the action of hydrogen or its equivalent. A substance becomes oxidized when oxygen or its equivalent is added on or hydrogen is removed, and reduction is just the opposite. Oxidation of inorganic substances is not of as great importance in the present consideration as in the case of organic substances. Organic substances seem to be more subject to change than inorganic, and one very frequent change observed in nature, or carried out designedly, is that of oxidation. If the oxidation be very rapid it is frequently accompanied by flame or glow. Substances may oxidize without burning, but all burning substances are being oxidized. Slow oxidization does not generate enough heat to render the substance luminous.

Examples of inorganic oxidation are when metals are heated in air. Copper when heated to redness takes on oxygen and changes from an orange-colored metal to a black, easily broken mass that is called copper oxide.[4]

The metal sodium has such a strong affinity for oxygen that it is changed to oxide [5] quickly, especially on the exposed surfaces, by contact with the air at ordinary temperatures. If this sodium oxide be wetted or allowed to remain in a damp atmosphere, it takes on water and becomes sodium hydroxide.

The oxidation of organic substances is exemplified by countless instances in what we see around us. The burning of coal or, better, of charcoal is one of the simplest cases of oxidation.[6] The black solid substance is consumed by oxygen to form the odorless, colorless gas, carbon dioxide. This gas has weak acid properties when mixed with water and forms carbonates with alkalies. (See page 12.) If the combustion be incomplete, being conducted with a minimum amount of air, carbon monoxide[7] is formed. This gas is colorless, has a faint odor, and is poisonous when inhaled. It can be burned to carbon dioxide[8] when sufficient air is present. Carbon monoxide is one of the chief components of most city gas and commercial producer gas. (See page 40.) Carbon can only be burned when the combustion is started by applied heat except in rare cases (spontaneous combustion, page 55). This is very fortunate, or we would not be able to get coal to the furnace before it would be burned.

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[4] $\underset{\text{Copper}}{2Cu} + \underset{\text{Oxygen}}{O_2} = \underset{\text{Copper oxide}}{2CuO}$

[5] $\underset{\text{Sodium}}{2Na_2} + \underset{\text{Water}}{2H_2O} = \underset{\text{Sodium oxide}}{2Na_2O} + \underset{\text{Hydrogen}}{2H_2}$

All organic matter will oxidize more or less rapidly when conditions are favorable. Matter that contains carbon and hydrogen when oxidized forms gases such as carbon dioxide and water vapor. Smoke that issues from chimneys contains chiefly these gases when white, and when the smoke is dark colored there are unconsumed carbon and fine dust of ashes present.

A chemical action (or reaction, as it is generally called) is governed by the affinity of elements for each

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[6] $C + O_2 = CO_2$. [7] $2C + O_2 = 2CO$. [8] $2CO + O_2 = 2CO_2$.

PLATE I.

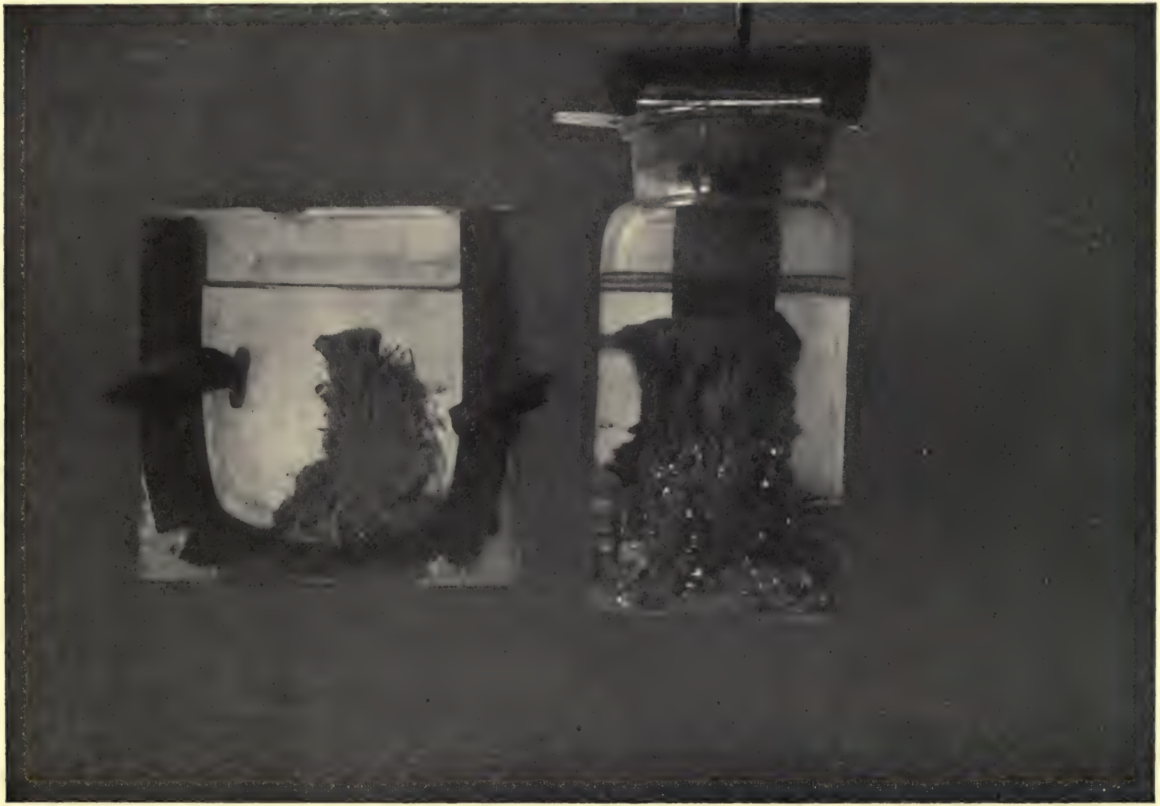


Photo by the Author.

Silver growing out of mercury in silver nitrate solution, on left. Lead growing from strip of zinc in lead acetate solution, on right.

other. This may be shown by the accompanying illustrations made by the author.

In Plate I (left) there was a one per cent. solution of silver nitrate in water, a little mercury was added which went at once to the bottom of the beaker. It was caught in a small receptacle which caused it to remain as a globule in the centre. Mercury has greater affinity for the nitric radicle (NO_3) than silver, so mercury goes into solution and silver comes out. Silver alloys with excess of mercury present and forms needle-like crystals which grow to form beautiful shapes of plant-like growth. This growth has been called "arbor Dianæ." Diana was an early name given to silver.

$$\begin{array}{ccccccc} \text{Mercury} & & \text{Silver nitrate} & & \text{Mercurous nitrate} & & \text{Silver} \\ Hg_2 & + & 2AgNO_3 & = & 2HgNO_3 & + & Ag_2 \end{array}$$

In the other illustration (on right) a strip of zinc was dipped into a clear solution of lead acetate. The zinc has greater affinity for the acetate radicle than lead, so they change places and the lead crystallizes quite rapidly in loose, moss-like forms.

CHAPTER II

HISTORICAL DEVELOPMENT OF CHEMISTRY

Quite a number of world-famous structures built over a thousand years ago have been the wonder of succeeding ages until to-day. Exact science is quite recent, however. Electricity was hardly known one hundred years ago, and modern chemistry had its beginning in the forepart of the nineteenth century. Chemistry is really a recent science, but many individual operations now called chemical were practised by the Chinese, Egyptians, Greeks, and others, long before the Christian Era. The Chinese had smelted ores and obtained metals therefrom as early as 1800 B.C.

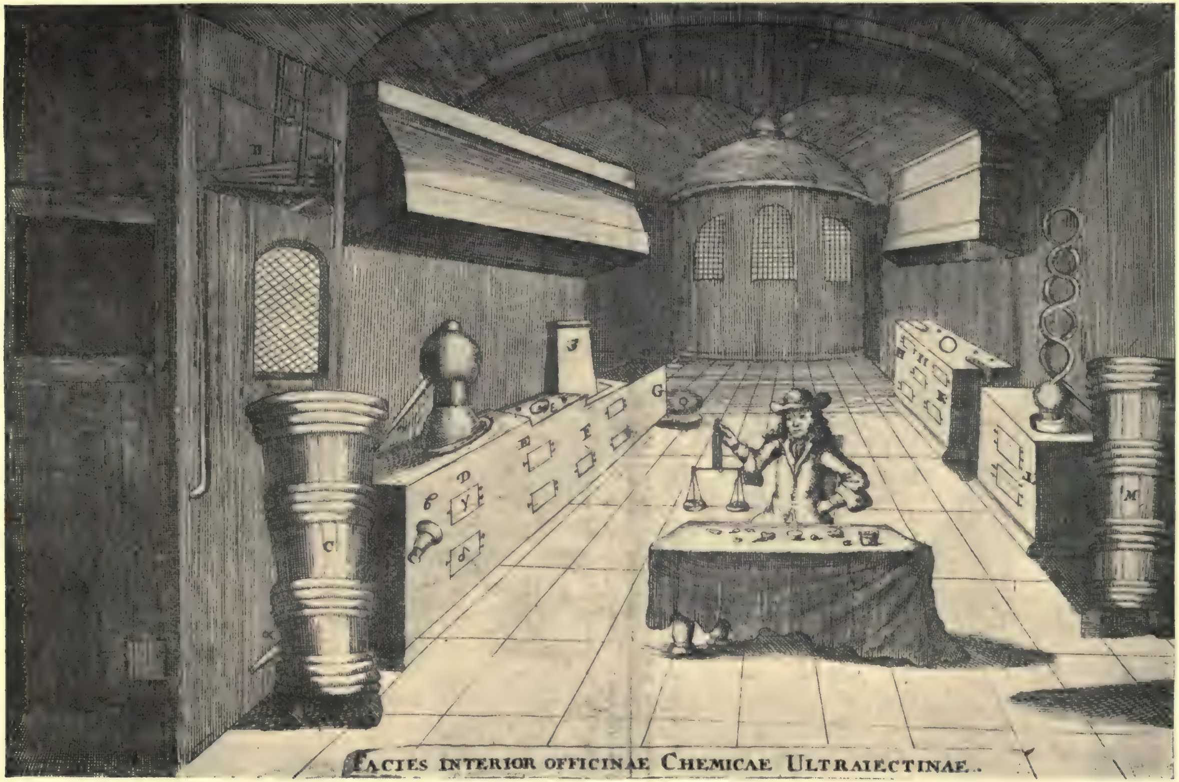
Everybody has heard of the alchemists. They were groping for two things. The belief was prevalent during this era that a way was to be found to convert baser metals into gold. They thought that the coexistence of lead, tin, silver, and gold, for instance, in nature indicated a transmutation of one into the other, as the properties seemed to be graded, with gold as the final stage. They also sought a means of greatly prolonging life. There were undoubtedly honest workers who believed that they would find out how to make gold, but there were also impostors who showed how gold was made by surreptitiously throwing pieces of gold into their crucibles while going through some process. They must have collected much money from would-be partners, investors, or patrons. During the time to which we refer there were great efforts made to find the *elixir of life* and the *Philosopher's stone.* The latter seemed to be something that when fused with a baser metal would produce gold.

From works in the author's possession, astrology seemed to play some part in alchemy, and this is not to be wondered at, as this pseudo-science was much practised during the middle ages and its influence survived probably until the beginning of the eighteenth century.

After alchemy had been well under way, Paracelsus (1493–1541), a Swiss, introduced the study of chemistry for medical purposes. This line of research was called *iatrochemistry,* and it did much to extend the science of chemistry, although it may not have done much for suffering humanity. The next development was based upon an entire misconception of what happens when substances, particularly metals, are heated strongly in the air. Hooke (1635, the inventor of watches) and later Stahl (1660–1734) were among the first to study combustion. Stahl thought that when a metal was stongly heated in the air it was dissociated into two components,—the calx (oxide) of the metal and phlogiston, a gas. There was a great contradiction in their reasoning. The metals increased in weight after the driving off of this so-called phlogiston because, as we now know, oxygen was taken on from the air, but they explained the phenomenon by saying that phlogiston was driven off by heat and as it had minus weight the calx could weigh more than the metal.

The fallacious theories of phlogiston were soon followed by a series of discoveries of the true elements, or ultimate components of substances. It might be interesting to note a few of the more important of these. Black noticed, on heating magnesium carbonate to redness, that a gas was given off which he called "fixed air" (carbon dioxide) because it would not take part in combustion. This gas, indeed, is not an element, as it is divisible into its components, carbon and oxygen; but this accurate observation shows that investigators were now on the path towards finding the true components of matter. He also recognized the fact that the same gas was obtained by adding acids to magnesium carbonate, burning carbon, or in breathing. This was a wonderful contribution to chemistry for this period. Black also discovered that solids, liquids and gases could absorb heat which might remain latent (be stored), as when a solid was liquefied or a liquid was vaporized; this was called *latent heat;* and he noticed that all substances possessed a certain

PLATE II.


FACIES INTERIOR OFFICINAE CHEMICAE ULTRAIECTINAE.
B
C
D
E
F
G
3
M

Early (1700) chemical laboratory.

amount of heat at any temperature, called *specific heat*. Thus, water holds more heat than copper, and copper more than lead, at any definite temperature.

The most brilliant investigator in his day was Priestley (1735–1804), who late in life lived in this country. Priestley discovered oxygen (which he called dephlogisticated air), nitrogen, nitrous oxide, nitric oxide and carbon monoxide. Cavendish (1731–1810) was a very brilliant experimenter, and, while he did not discover many elements, he did some very exact work, such as finding that air is a definite mixture of oxygen and nitrogen. He discovered hydrogen, and found that when hydrogen was burned in air water alone was formed, thus establishing the composition of water.

A great generalization was discovered or announced by the brilliant French chemist Lavoisier. This is so important that it should be emphasized. *Matter is indestructible.* Nothing is lost in the universe. If one burns oil in a lamp the weight of the products of combustion, water (H_2O) from the burning hydrogen (H_2) of the oil and carbon dioxide (CO_2) from the burning carbon (C_2) of the oil exactly equals the weight of the oil plus the weight of oxygen uniting with the oil during combustion. If copper be heated to redness in the air it unites with oxygen,[1] and the gain in weight exactly corresponds to the oxygen absorbed. Nowhere is the indestructibility of matter so clearly shown as in nature. Not even a leaf that falls from the tree is wasted, for sooner or later all its carbon returns to the air as carbon dioxide and the hydrogen forms water again. The mineral residue improves the fertility of the soil. Berthollet (about 1800) published a work in which he claimed that elements united with each other because of *chemical affinity,* which he recognized as a force something like gravity.

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[1] $Cu_2 + O_2 = 2CuO$.

This was a very important period at the beginning of the nineteenth century, for elements had been discovered on and off for a century; the list of elements now undoubtedly is incomplete, but there were generalizations introduced at this time which are the fundamental laws of chemistry to-day. Proust (1801–1806) announced that elements combine in definite proportions; for instance, about 23 parts by weight of sodium always require about 35.5 parts of chlorine for combination to make sodium chloride (table salt). Dalton then found that an element could combine with more than one proportion of some elements, but still the quantities were fixed and simple multiples of the least quantity. Mercury combines with two fixed quantities of oxygen, nitrogen with as many as five different but fixed quantities of oxygen. Proust's law is the law of *definite proportions* and Dalton's is the law of *multiple proportions.* The first law enables us to calculate exactly the proportions to be used when we want to carry out a chemical process. For instance, if we want to neutralize the fatty acid in an oil, we ascertain the amount required in a small sample, say a gramme, by cautiously adding an alkaline solution of known strength, and we then add the calculated amount of alkali to the large batch. When the proportions of two elements vary according to the second law, we generally say they are in different states of oxidation. When mercury has one atom of chlorine ($HgCl$) it is called mercurous chloride or lower state of oxidation (chlorine being considered like oxygen), and when it has two atoms of chlorine it is called mercuric chloride ($HgCl_2$). These affixes, *ous* and *ic,* always have the same significance, and indicate whether a metal has or has not the maximum amount of non-metal in combination.

During the eighteenth century there were some important laws of gases discovered by Boyle and others. Such important principles as that a gas expands directly as the temperature were enunciated. We see exemplifications of this in the formation of air currents. When an area becomes heated the air expands and is made lighter. It then ascends, and air is drawn from other sections to fill the partial vacuum. The compression of a gas creates heat and the expansion of a gas absorbs heat (seems to create cold). Application of this property of gases is made in the artificial creation of cold.

Just when modern chemistry began is hard to say. A few modern chemical substances, by other names in most cases, were known in early Roman times, as shown by the writings of observers like Pliny. There was, however, little real progress made until the eighteenth century, when some of the most important chemical elements were discovered, as we have seen. About the beginning of the nineteenth century chemical substances were crudely classified, although the names of most of these substances did not follow our present nomenclature. They spoke of "vegetable alkali" when they meant potassium salts, "mineral alkali" for sodium salts, "volatile alkali" for ammonium salts and combinations. They had the right idea, however, by this time.

It was early in the nineteenth century when sulphuric acid and sodium hydroxide were made on a large scale, and that might be said to have been the beginning of the modern chemical epoch. The most recent portion of this era has been replete with the production of the finer organic chemicals, such as artificial dye colors, synthetic remedial agents, and *electric furnace products*, such as artificial graphite and carborundum, calcium carbide, phosphorus, and special steels and alloys. Electrolytic sodium hydroxide and sulphuric acid, made by the action of the oxygen of the air on sulphur dioxide in the presence of a catalytic or contact substance, are also great modern improvements in the chemical field, and "air saltpeter," or nitrate, made by the union of the nitrogen and oxygen of the air under the influence of the spark discharge of the electric arc, is rising in importance.

Plastic substances, such as vulcanite, celluloid, vulcanized fibre (made by the action of zinc chloride on paper), and a very recent plastic made from carbolic acid by the action of formaldehyde, called, from the inventor, "Baekelite," are chemical products of the last half century. We will see, as we go on, what chemistry has done for many of the important industries, with the exception of the purely chemical industries, such as the manufacture of chemicals themselves. These important lines of work are not directly of interest to the average person, so they will not be discussed here, as this book is designed to be the "Chemistry of Familiar Things."

CHAPTER III

THE PERIODIC SYSTEM OF ELEMENTS

CHEMISTRY possesses a sort of revelation. It is called the periodic system. This system is shown by making a list of the elements in the order of their atomic weights, or weights of the elements relative to the weight of the hydrogen atom, forming several series in horizontal lines. It is then found that similar elements will recur in vertical rows.

Elements may therefore be grouped according to relationships, and these groups or families occur naturally in the same columns in the periodic system.

GROUPS

Sodium	Calcium	Carbon	Oxygen	Chlorine
Lithium	Glucinum	Carbon	Oxygen	Fluorine
Sodium	Magnesium	Silicon	Sulphur	Chlorine
Potassium	Calcium	Germanium	Selenium	Bromine
Rubidium	Strontium	Tin	Tellurium	Iodine
Calcium	Barium			

This revelation of the orderly sequence of the atomic weights going hand-in-hand with a gradation in properties of the elements was discovered nearly simultaneously by Lothar Meyer in Germany and Mendeléeff in Russia in 1868. It was found that there were some gaps in the table, and Mendeléeff went so far as to predict what would be the properties of elements for these places, should they ever be discovered. Vacancies have now been filled by the discovery of gallium, scandium, and germanium, besides a complete series of atmospheric gases: helium, neon, argon, krypton, and xenon.

When the principle of the periodic system was enunciated, chemists began to speculate as to the composition of matter afresh, and ever since this time efforts have been made to solve the riddle. It was first thought that all matter was built up from hydrogen, as the elements at first seemed to have as atomic weights multiples of one or integers, but now accurate work has shown that not many of them are whole numbers. The belief is still prevalent that all elements are aggregates of some primordial substance other than hydrogen.

The analogy of the periodic system to the harmonic series of music is very striking. Elements of like character recur just the same as musical notes of like character. Sodium, which is much like lithium, has an atomic weight that brings it in the same vertical row as lithium, and potassium comes under sodium, and each is sixteen more in atomic weight than the one above it. Further down the column the interval between related elements in the vertical row is more than sixteen.

Germanium had not been discovered when the principle of the periodic system was enunciated. One of the elements which Mendeléeff anticipated, should it be found, might fill this void in the table was called by him *eka-silicon.* He described its properties which were to be midway between those of silicon (Si) and tin (Sn). Germanium (Ge) when discovered was found to occupy this place in the table both because of its atomic weight and the properties it possessed. Eka-silicon was then removed from its place as substitute and germanium has occupied it ever since. This shows the great importance of the periodic system. Some scientists think some of the still missing members of a completed table might exist in other planets than on this earth, and that in the original nebula from which the planets came all elements that have places indicated in the periodic system were to be found. It would be a wonderful demonstration of the completeness with which nature develops systematic relationships if this were the case.

CHAPTER IV

THE CHEMISTRY AND PRODUCTION OF LIGHT

LIGHT itself is, primarily, a mechanical or physical manifestation. Chemistry, however, plays a very important part in the artificial creation of light, and, as we have that to deal with, it does not seem inappropriate to devote a chapter to illumination.

Light is intangible. It cannot be weighed as air can, but is a manifestation of energy and is transmitted through space, where there is air or through a vacuum, through glass or water, by a wave-like motion of a hypothetical, highly attenuated fluid known as ether. This does not mean the liquid used for anæsthesia, but the name in this connection refers to the medium of propagation of impulses such as those of heat and light.

Sound waves are different from heat and light, as they can only travel in dense media, such as air, water, metals, etc., and they travel faster in the latter than in the former. The subject of vibratory impulses has been so thoroughly studied that the lengths and the frequency of the various kinds of wave motions have been measured accurately and the knowledge gained has accounted for many observed happenings. When a piece of iron is slowly heated in the flame, it at first radiates heat, and as the frequency of the wave motions becomes greater it radiates light,—first, red rays, then yellow, and finally, if the heat be very intense, a white light is emitted. The red waves are longer and of less frequency than the blue. When white light passes through a glass prism, the waves are differently acted upon and are separated. The red rays are diverted less from their previous direction than the violet, which accounts for the separation of the colors in a prism projection. This is exemplified in light from a clear sky. Refracted by suspended particles, the blue rays are diverted more than the others and give the blue appearance to the otherwise colorless clear sky. The color of water when relatively clear and of moderate depth is due to very finely suspended matter which deflects some rays of light more than others. It may thus look green or blue, due to the amount of deflection. Besides the wave lengths producing the ordinary colors of the spectrum which affect the retina of the eye, there are those of less frequency than red and others of greater frequency than violet. They are known as infra-red and ultra-violet rays. These ultra-violet rays affect the photographic plate and have a good deal of interest in other ways. Ultra-violet light, for instance, is sterilizing in its effect and induces chemical changes.

The colors at the red end of the spectrum give the most heat, in the middle the most light, and the ultraviolet is the most active in producing chemical change but gives very little heat.

Light travels through space in straight lines with a velocity of about 186,000 miles (equal to over seven times around the world) in a second. The intensity of light on a given surface is inversely as the square of the distance from its source. At twice the distance a given unit of surface receives one-fourth the light. It would seem that a given amount of light placed in different parts of a room would give better results than if placed as one source of light. Light diffused by ground glass is easier on the eyes, because of its lessened intensity.

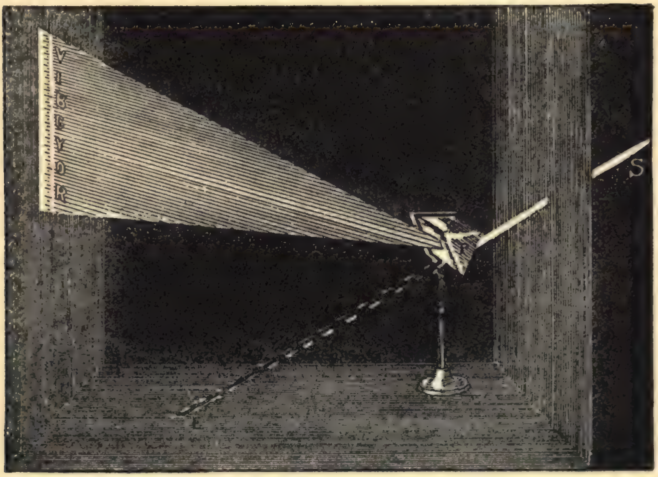

Fig. 1.—Solar spectrum.

Light is reflected, absorbed, or transmitted by bodies upon which it impinges. A transparent object is one that transmits most of the light and reflects or absorbs very little. A colored transparent substance is one that transmits part of the spectrum and absorbs the rest. Bodies that are colored when seen by reflected light likewise absorb all but the rays of the color that is reflected to the eyes.

If red is removed from the spectrum the other colors combine to form bluish-green, or the complementary color to red. Purple is the complementary color to green, ultramarine blue to yellow. When refined sugar is slightly yellowish, the color known as ultramarine is added to neutralize the yellow and it appears white. When manufacturers want to make a slightly yellowish product look pure white, they pack it in bluish paper, which throws a blue light through it and neutralizes the yellow.

The writer always had the feeling that daylight was of rather fixed quality, but when these proofs were submitted to a friend, who was president of the National Illuminating Engineering Society, among other points he queried the word *normal* as an adjective used with daylight, for the reason that daylight was variable from an analytical point of view. Northern light on a clear day contains more blue rays due to the light coming from the blue sky. Of course if north light is reflected from a building nearby, it is not true north light but a reflected south light, etc. The colors of objects are greatly modified by the incident light, as all know and have seen exemplified in theatres where different colored lights are thrown upon the stage and give colored effects to objects upon which they strike. Artificial lights are all different from any variety of daylight or even white light (most daylight is a bluish shade of white light). A lantern [1] may be used with gas that gives daylight of the northern sky variety. This has been accomplished by the interposition of a screen of the right shade of blue. This glass was not on the market and had to be made specially for the purpose. This device is used for matching colors in dyed or printed goods, etc. Daylight glasses have also been made to neutralize yellow light, so that with these spectacles one can see colors indoors as he should. Artificial daylight has been made from electrical sources in two ways: First, two lamps are used, such as the Moore lamp, which gives a yellow light, and a Cooper-Hewitt lamp, which gives a greenish-blue light; the combination of these two is said to be nearly the same as daylight: second, a screen can be used with electric lights about the same as with gas mantles.

Light is essentially reflected when it is returned from a surface, as from a mirror; transmitted when it goes through in a straight line, as through a window-pane; and refracted when it goes through media, such as glass or water, with a difference in direction, taken at the surfaces of the substance. Thus, an oar in the water seems bent to the eye, as the light reflected by the oar does not travel a straight course to the eye. Interesting phenomena connected with light are those included under *phosphorescence.* Some mineral substances show a luminosity called phosphorescence after exposure to visible light rays or invisible ultra-violet rays. This is true of willemite (anhydrous zinc silicate), calcium sulphide, etc. Some substances, such as barium platinocyanide, calcium tungstate, quinine sulphate, and dyes such as fluorescein, glow only when excited by rays such as ultra-violet or those evolved from radium. It is supposed that the violet and ultra-violet rays cause a condition of stress in the substance which causes it to give off light for a while in the dark. Fireflies and minute organisms in decaying wood seem to generate light in much the same way that food energy is converted into heat energy in higher animal life. Some bacteria or protozoa in the water have this effect, especially when the water is agitated, as when a person swims in the water and air is introduced. This effect is noticeable to best advantage in September, and if any one swims or the water is splashed at night the effect is quite beautiful.

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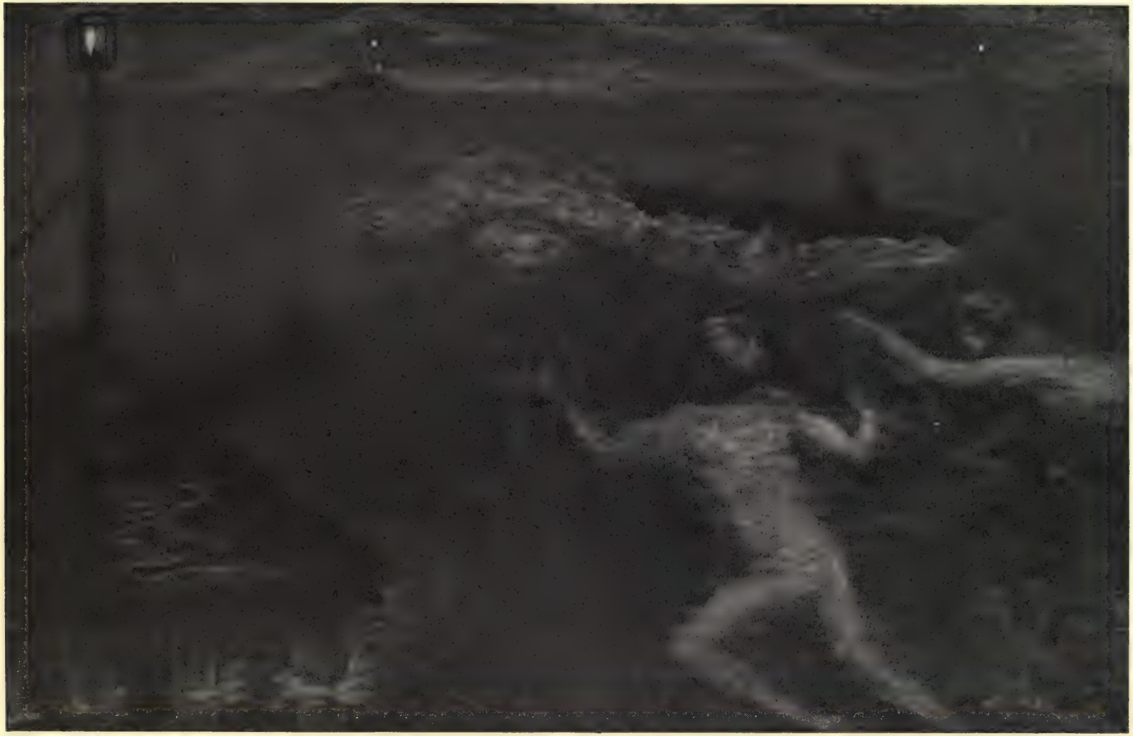
[1] The invention of Dr. H. E. Ives.

PLATE III.



From a sketch by A. H. Sadtler.

Effect of light producing bacteria in water stirred up in swimming, rowing, etc.

Light has a marked chemical influence upon a great many substances. The bleaching action upon many dye colors is well known and is due to the influence of the ultra-violet rays, chiefly in inducing oxidation or other chemical change. In the dark, linseed oil becomes deep in color, due to a reducing action upon the pigments of the oil. The direct sunlight causes a reverse action and oxidizes the pigment so that it becomes colorless.

White-lead paint is easily darkened by hydrogen sulphide gas, due to the formation of lead sulphide (PbS). In the presence of the ultra-violet rays of the sun the lead is oxidized in the presence of the hydrogen sulphide to lead sulphate ($PbSO_4$), which is white, so that the white paint does not seem to have been altered, and it is only where hydrogen sulphide gas acts on white lead in the dark or absence of strong light that the paint is discolored.

According to Freer and Gibbs,[2] the ultra-violet rays of direct sunlight are the cause of sunburn, and nature (with most people) protects herself against their continued influence by a process of pigmentation. This pigmentation became a racial characteristic with the inhabitants of the tropics, especially in Africa. These same writers state as a fact, what has long been believed, that the color of the clothing has a direct influence on the comfort of the individual, irrespective of the weight of the goods, red clothing being more heating than white. White clothing is the coolest, and, if it is loose and more or less pervious to air, it enables the perspiration to be evaporated, which is nature's chief process for its self-cooling.

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[2] VIII International Congress of Applied Chemistry.

The theoretically perfect light is one that radiates no heat, such as the light from fireflies. But while no perfect light has been made commercially as yet, there have been great strides in the matter in recent years. The Welsbach gas mantle was the first great step in this direction, and the last improvement in getting light rather than heat by the expenditure of energy was in the introduction of the tungsten incandescent electric filament.

Table of Light Efficiencies.[3]

Fireflies	about 100 per cent.
Acetylene flame	4 to 5 per cent.
Welsbach burner	4 to 5 per cent.
Carbon filament, electric (4 watts per candle)	2 to 3 per cent.
Tungsten filament, electric (1.25 watts per candle)	8 to 10 per cent.
Electric arcs	8 to 17 per cent.
Mercury-vapor electric lamps (glass)	5 to 6 per cent.
Nernst glower	5 per cent.

These are efficiencies with regard to the proportion of light to total radiation, and do not refer to cost to the consumer. Ultra-violet light not covered with glass is dangerous to the eye, for physiological reasons. Glass almost completely absorbs ultra-violet light, whilst quartz does not. The latter is therefore used where chemical effect is desired, and a glass cover protects the eyes when used as an illuminant. Of the present artificial light sources the mercury-vapor lamp with silica tubes is productive of the largest amount of ultra-violet light except arcs from iron or silicon.

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[3] Mostly from E. P. Hyde: A paper entitled "Physical Characteristics of Luminous Sources," Lectures on "Illuminating," *Engineering*, vol. i, p. 25.

A very interesting experiment that can be performed in the home is to collect in a quart jar as many fireflies as it will hold to advantage (so that the sides are filled with them) and to put it on the centre-table at night in a room not otherwise illuminated. It will be found that they create a very mellow light that one can read by, and if a long exposure is given a photograph can be taken by its aid. The writer expected to collect enough of these light-giving flies this summer to take such a picture for the purpose of illustration here, but neglected, for some reason, to do so.

The sources of light most used are gas, oil, electricity, acetylene, candles and denatured alcohol.

Gas is obtained naturally in some localities, such as Western Pennsylvania, West Virginia, Ohio, and Kansas, by drilling into the deeper rock strata, and when so obtained is a cheap source of light. It is largely composed of methane (CH_4), the member of lowest molecular weight of the series which includes petroleum products, such as gasolene, kerosene, and paraffin. Gas may be made artificially, however, in retorts by heating bituminous coal. Besides gas, tar and ammonia are evolved and coke is left, which is used for making iron in blast furnaces and for domestic use.

Coal + heat = coke + gas + tar + ammonia.

The composition of illuminating gas ought to be well known to everybody. Most city gas is a combination product made by driving steam through glowing coke or hard coal, which is called *"water gas."* It is essentially a mixture of hydrogen and carbon monoxide. This gas, however, would not burn with a yellow flame, so a semi-refined petroleum product called *gas oil* is injected into the carburetter of the apparatus in which the water gas is made. This gives to the gas the constitutents called *illuminants.* Sometimes this *carburetted water gas,* as it is called, is mixed with retort gas, which comes from the heating of bituminous coal in retorts or muffles. These additions to water gas give it odor, so that its escape is easily detected, which is a safeguard.

	Water gas	Water gas, Philadelphia 1911	Retort gas
Hydrogen (H)	52.0	36.05	49.0
Carbon monoxide (CO)	38.0	26.30	7.2
Methane (CH_4)	1.0	21.45	34.5
Illuminants	...	11.56	5.0
Nitrogen (N)	3.0	1.20	3.2
Carbon dioxide (CO_2)	6.0	2.60	1.1
Oxygen	...	0.84	...

Most city gas is a highly refined product, as the tar that forms in the manufacture is very carefully removed and is utilized to make many things of value, such as benzol, toluol, and coal-tar naphtha (all solvents for many useful purposes); naphthalene, a white, flaky, crystalline substance, sometimes called coal-tar camphor; anthracene, used for making coal-tar colors; carbolic acid and various forms of disinfecting creosotes; roofing pitch, and road oils. Ammonia is washed out with water and is refined for refrigerating and household use. Sulphur compounds are absorbed by means of specially prepared iron oxide. These impurities are valuable by-products that cheapen the cost of making gas and render it a satisfactory article for use.

There is a great deal seen in the newspapers about coal-tar colors. Their relation to coal-tar is a true one, but they are several generations removed. Pure benzol or pure toluol (volatile liquids distilled from coal-tar) are generally the starting-points, although naphthalene and anthracene are much used for the colors fast to light. If benzol is the starting-point, it is generally treated with nitric acid, which makes nitrobenzene ($C_6H_5NO_2$). This is then by treatment with iron and sulphuric acid converted into aniline ($C_6H_5NH_2$), from which the colors are made by special reactions. The color known as "butter yellow" is made from aniline by treatment with nitrous acid. In country houses gas made by passing air over gasolene is often used. This kind of gas is practically non-poisonous.

Oil is obtained by the distillation of crude petroleum in large, horizontal, cylindrical vessels holding one thousand barrels each. Gases come over first, which a passage through a condenser fails to liquefy; these gases are burned under the stills; then gasolene comes off and is condensed. Next kerosene or burning oil comes over, and then lubricating oils and paraffin. It used to be the object to get all the kerosene possible, and from 60 to 75 per cent. of Pennsylvania crude was made into kerosene, but now the demand is more for gasolene, due to the growth of the automobile industry and other uses, such as the internal combustion engine. By changing the system of distillation, such as distilling with pressure, more gasolene is obtained. It may not long be desirable to make so much gasolene, however, as inventors are at work on kerosene carburetters, and the writer has already seen an automobile apparently run very nicely on nothing but kerosene after gasolene was used to start it.

The writer has been under the impression that rooms in which gas was burned required more special ventilation than where electricity was used. From tests made by Dr. Samuel Rideal, of London, England, it appears that currents of air caused by the lifting power of heated gases produce enough ventilation themselves to take care at least of the carbon dioxide and water vapor formed in combustion, and that organic matter from the lungs and bacterial content of the air are diminished by the combustion in the flame.

We have gone into the subjects of gas and oil somewhat at length. With reference to electric lighting, the subject is not so chemical. Chemistry, however, has had a great deal to do with perfecting the filaments, especially with producing fine tungsten that was tough enough to be drawn out into fine wire. The first lamps were very fragile, but now there is a fair chance that a lamp will last long enough to be of real value. Greater purity in the metal renders it less brittle, and the crimp of the filament reduces the tension that tends to break it when cold. In spite of all precautions it is still apt to stretch and loosen the electrical contacts with the copper wire support, but often a change from a pendent to an upright position, or *vice versa,* will render it useful again. Tungsten is used chiefly because it is a metal that can be heated by electrical resistance to an intense white heat without melting, and the higher a substance is heated the more light is radiated in proportion to the power applied. More efficient light, as regards the power applied, can be obtained from the tungsten lamp by the momentary application of a greater than the normal current.[1] This flash of light can be used for photographic purposes, due to its great brilliancy. An ordinary 25-watt tungsten lamp will produce 20 candle power, while a 50-watt carbon lamp will give only 16 candle power.

RELATION OF WATTS AND CANDLE POWER OF RECENT IMPROVED TUNGSTEN LIGHTS.

Watts	Candle power	Watts	Candle power
10	8	60	50
15	12	100	90
25	20	250	240
40	32	400	400

The variation in candle power due to voltage is 50 per cent. less than with carbon-filament lamps.

The color of the light of the tungsten lamp seems to the writer to be quite tolerable, especially if the reading lamps are not too powerful. For instance, this is being written with a single 15-watt tungsten lamp on my table and no other light in my small study, and my eyes never feel strained, although I write on white paper but avoid direct reflection.

The Illuminating Engineering Society has issued a booklet called *"Light, its Use and Abuse,"* from which the following paragraphs are quoted, which have their point largely in the physiological action of the pupil or opening of the eye regulated by the iris and the effect of light upon the same. The pupil can accommodate itself to the amount of light directed toward the retina, if given a certain time for the change, but cannot adapt itself to sudden changes nor to the simultaneous action of bright lights while endeavoring to discern less brilliant objects.

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[1] When filled with nitrogen or argon more efficiency is attainable.

"You must get enough light to see by, and, as you see things chiefly by the light which they reflect, it is evident that dark-colored objects which reflect light badly require more light than do light-colored objects to see them comfortably."

"Daylight is naturally well diffused; but artificial light, poured out as it is from mere points or narrow surfaces, needs to be tempered or softened by shades."

"In any artificial lighting the lamps should be so well shaded that the eye does not see them directly nor brilliant reflections from them."

"A method frequently used for combining some of the advantages of both direct and indirect lighting is to place the lamps in a bowl of diffusing glass. This bowl reflects upward part of the light as in indirect lighting and lets through part as in direct lighting."

"No reflector ever increases the total light that streams out of a lamp: it only puts the light where it is needed instead of letting it go unguided."

"Because dark walls absorb light strongly instead of reflecting it, they demand much stronger lamps for sufficient illumination than do light walls. A very dark wall-paper or a dark wood finish may require three or four times as much light as a really light finish. Dark reds, greens, and browns reflect only 10 to 15 per cent. of the light which falls on them. White, cream color, and light yellowish tints may reflect over one-half the light."

Electricity is produced in *primary batteries* by chemical action. The batteries known as secondary batteries store electrical energy. As all these processes are chemical, it might be well to consider them briefly. The principle of the primary battery depends upon there being an electrolyte, consisting of an acid, an alkali, or a salt, dissolved in water to carry the current; a metal forms one pole, which tends to go into solution and in doing so produces electrical energy which passes through the conducting solution or electrolyte to another metal, carbon, or other substance, that is less energetic electrically or is electro-negative to the metal generating the current. Well-known elements and compounds may be arranged in a series in which the lower numbered members will generate current if placed in a cell containing dilute acid with the substances of higher numbers.

1. Magnesium
2. Aluminum
3. Zinc
4. Cadmium
5. Iron
6. Nickel
7. Tin
8. Lead
9. Antimony
10. Bismuth
11. Copper
12. Mercury
13. Silver
14. Platinum
15. Gold
16. Carbon
17. Copper oxide
18. Lead dioxide

At the negative pole hydrogen is evolved unless an oxidizing agent, such as manganese or lead dioxide, absorbs it by chemical action. The current passes to the outside circuit through the electro-negative pole or element, and finally returns to the point of formation, after a drop in intensity, called *voltage.* The voltage of an electrical circuit is just like the *head* or *pressure* in a water circuit. The normal voltage of a zinc-sal-ammoniac-carbon dry cell is about 1.5 volts when fresh and 1.0 volt or less when run down. The amount of current passed is measured by a unit called the *ampère.* The amperage of a cell depends upon the resistance, such as the winding of the electro-magnet of a bell or the filament of a lamp. The more the resistance the less the current. The types of primary batteries probably most used are (1) zinc-carbon cells with ammonium chloride (sal ammoniac) solution as the electrolyte. These generally are filled with absorbent material to keep the liquid from spilling when not kept upright, and the carbon is surrounded by manganese dioxide and graphite to absorb the hydrogen that would otherwise pass off. These cells generally give out by alteration of the electrolyte, and a little additional life may be given then by putting in some fresh sal ammoniac solution. They are called *dry cells.*

Another cell much used is (2) the Edison-Lalande, which consists of zinc rods as generating elements, an electrolyte of sodium hydroxide, and copper-oxide plates. These plates are black when fresh, but the hydrogen which they absorb turns them red from formation of metallic copper. In handling this cell it is well to be careful about getting sodium hydroxide solution on the hands, as it is very caustic. The voltage of this cell is low, but it lasts a long time when not in use or on open circuit. Other cells are used for some special purposes, such as telegraphy. For household use where one has an alternating current, so-called "toy" transformers are useful for bell ringing, as they never *go dry* or *play out.*

Secondary cells or storage batteries are generally made up of spongy lead plates as negative poles, diluted sulphuric acid as electrolyte and lead-peroxide plates as the positive pole. They generate current by the union of lead with the sulphuric acid and the action of hydrogen on peroxide of lead. Current is obtainable when fully charged to quite a considerable extent, but gradually the intensity diminishes, as is indicated by a lowering of the voltage. This is largely accounted for by the union of sulphuric acid with lead oxide at both poles. This makes the electrolyte less of a conductor (more resistance) due to loss of acid, and there is more resistance to the passage of the current at the poles due to lead sulphate being present and less active matter. The Edison storage battery consists of iron and nickel peroxide with an alkaline solution as an electrolyte. This cell costs more for the power generated or stored, but is lighter for the same power and therefore is useful for portable purposes.

Acetylene gas is generated by adding water to calcium carbide, an electric-furnace product made by heating coke and lime. This form of illumination is used in detached installations and the light is very intense and concentrated; therefore, the flames should always be seen through ground glass or glass that has been treated, to absorb the most irritating rays. Alcohol is used for lighting in Europe, but is rather expensive for use in this country. It must be used in connection with mantles, as it otherwise gives only a bluish, but hot, flame.

Mantles used for gas illumination are composed of oxides of rare elements. They are generally a mixture of ninety-nine per cent. thorium oxide with one per cent. of cerium oxide. After the protecting substance (collodion) has been burned off, they are mechanically weak, and should be protected from outside influences, such as matches and tapers poked into them for lighting and knocks or vibrations. When taken care of they last a long time. Those made from artificial silk are relatively strong.

Matches in this country are mostly of two kinds,—the *double dip* or tipped, strike-anywhere match and the *safety match* which must be struck on the box. The older form of strike-anywhere match, with no tip and made with white phosphorus, is no longer used. For one thing, it is no longer legal to use yellow phosphorus, due to the danger of the operatives getting "phossy-jaw." Phosphorus sesquisulphide is now used in strike-anywhere matches or in the very tips of them. This new substance seems to the writer, who has visited match works frequently, to be a cure worse than the disease. Phosphorus sesquisulphide may not produce necrosis (phossy-jaw), but it is very hard on the eyes of those who make it, and even the match makers have complained of it. It is highly probable that in a few years legislation will take hold of the matter again, and direct that only red phosphorus be used, as in safety matches.

Matches are essentially mixtures of some form of phosphorus, potassium chlorate or oxidized red lead, powdered glass, zinc oxide, rosin, glue and coloring matter. In safety matches part of the composition (the red phosphorus) is on the box, so that the matches themselves will not ignite without the boxes. Recent improvements in matches include the impregnation of the stem of the match with a fire-resisting chemical, such as sulphate of ammonia, so that sparks will not be retained by a supposed burned-out match-stick and start up a blaze. People can then throw them into the waste-paper baskets with impunity! Paraffin applied to the splint before the composition is added holds the light and causes the wood to burn a reasonable time.

There are several other ways in vogue for striking fire other than the use of matches. The older of these is with a small *platinum sponge* or *platinum black,* which when dipped into wood alcohol and exposed to the air causes the ignition of the wood alcohol. This is an example of catalytic action. The platinum seems to act by giving great surface to the alcohol and condensing air or oxygen in contact with it, which causes instant oxidation, heat, and consequent flame. The other and more recent method is to draw a pencil point of cerium-iron alloy over a piece of a file, which causes a voluminous sparking, and these sparks are used to light gas or gasolene vapor. Cerium seems to be oxidized by the heat of friction in the presence of air, and as it momentarily burns by oxidation it gives a flame. It has recently been found that uranium carbide is a pyrophoric substance like cerium alloy.

CHAPTER V

HEAT, COMBUSTION, AND INSULATION

We need a regular supply of the manifestation of energy called heat very nearly as much as we need a regular supply of air, and in a large part of the world artificially created heat is a very vital necessity. The more enlightened people are, the more heat they seem to need in countries that have winter. We can keep warm enough for nature's requirements by clothing alone, which means the shutting in and utilizing the heat generated by the combustion of our food, but most of us want greater freedom of action, and therefore use a great deal of fuel to keep our houses temperate instead of being bundled in clothing in winter time. Too much clothing interferes also with the respiration through the skin, which undoubtedly is a vital necessity.

At low temperatures, without the special precaution of heavy clothing or heated shelter, we are unable to create heat fast enough to maintain the bodily functions, no matter how much we eat, unless we are taking violent exercise, when more heat would be created, due to active tissue consumption. Unless a person is in energetic motion he should not tolerate a sense of cold if he can prevent it, although parts of the body may be cold if the trunk is warm.

We notice heat directly by our sense of touch. Through a relatively narrow range we can tell to what extent heat passes from us to an object if it is cold or from the object to us if it is warm, and grade these sensations in a rough series. We have all come in contact with colder and hotter substances than were comfortable, and few repetitions have been necessary to convince us that better means of measuring temperatures should be used than the sense of touch. We have adopted instruments for registration of heat which we call thermometers, on which differences of temperature are registered in degrees due to the expansion of mercury in proportion to the temperature. The two chief systems are the Centigrade (or Celsius) and the Fahrenheit. The former is the more rational and is used in all scientific work and generally on the continent of Europe. We have inherited from England the inferior unit, or Fahrenheit degree. The units of length, volume, and temperature, which have come to us from the mother country, are all inferior to the continental or decimal system of units. It is something to be thankful for that we did not adopt the English monetary unit. The two most easily determined points with reference to heat are the melting point of ice and the boiling point of water at the sea level.

COMPARISON OF TEMPERATURES.[1]

	Melting point of ice	Boiling point of water
Fahrenheit (F.)	32°	212°
Centigrade (C.)	0°	100°

Science teaches us that the molecules of all substances are in vibration, due to the heat they possess, and the higher the temperature the greater the movement and consequent expansion of liquids (such as mercury) and some solids. By calculation it has been deduced that at a temperature 273° below zero C., all such motion would cease, and this is called the *absolute zero*. This point is the basis of calculations as to the volumes of gases, but is of no significance in ordinary heat measurements. Artificial means of creating cold, however, have gone almost this far in special research work, as Ohmes has obtained —272° C. by evaporating liquid helium.

Ordinarily heat is considered as coming from three sources: *the sun, chemical combustion,* and *mechanical means.* In the last analysis, however, there are really only two,—the heat of the sun and chemical heat, as mechanical heat comes from the combustion of coal, oil, etc. (chemical source), water-power or the wind. The last two are due to the solar heat exercised in elevating the water by evaporation and causing the changes in temperature which produce differences in density and create air currents.

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[1] It will thus be seen that 180 degrees F. = 100 degrees C. To convert Fahrenheit to Centigrade, subtract 32, multiply by 100, and divide 180. To convert Centigrade into Fahrenheit, multiply by 180, divide by 100, and then add 32.

The sun is mostly in the vaporous condition, at a temperature of about 6000° C., and is a sphere because of its force of gravity or cohesion. The radiations from the sun are so intense that a great deal of light is given off, as well as heat. As there is only a thin coating of atmosphere around the earth and in the neighborhood of the sun, it is evident that the heat and light are transmitted through the vacuous space between the sun and earth by reason of the vibratory motion and not by conduction. The intervening vacuum is not heated.

Heat from chemical sources is well known to us, but it is not very generally appreciated that the source is chemical. In the first place, all the heat of the body is chemical heat. The food is the fuel for this low-temperature heating system. Probably the little fires all over the body would be rather hot if the blood did not circulate by means of a pump designed for the purpose, the blood carrying off the heat as fast as formed. Coal fires are the prevalent means of creating artificial heat, but it does not make any difference in principle if the fuel be wood or lignite, peat or coal, oil or gas, as the combustible contains carbon and hydrogen, which burn with air to produce carbon dioxide and water.

TABLE OF FUELS.

Fuel	Hydrogen	Carbon	Oxygen and nitrogen	Ash	Fuel value in in B.T.U. per lb.
Cellulose	6.2	44.5	44.3		7,500
Wood	6.0	50.	44.0		7,200– 7,500
Peat	4.5–6.8	50–64.	28.6–44.		9,000–10,800
Lignite	5.	60–75.	20. –35.		10,800–12,600
Soft coal	4. –6.	75–90	5.5–15	5–10	13,500–15,000
Anthracite	1. –2	90–95	3.	10–20	12,500–14,000
Gasolene	variable		...	...	about 21,000
Kerosene	"		...	...	" 20,000
Benzol	8.0	92.0	...	...	18,450
Crude oil	variable		...	...	about 19,000

The practical utilization of heat, whether in steam boilers for factories or in hot-air, steam or hot-water furnaces of houses, is at best inefficient. When combustion takes place gases are formed, first, either by distillation from the fuel itself or by the partial combustion with oxygen. If by distillation, hydro-carbons are largely formed. If by the partial combustion by air, carbon monoxide is formed. There is generally a composite gas containing both these elements first formed, which burns above the fuel bed to carbon dioxide and water vapor. The gaseous products contain a large portion of the heat, and some of this is extracted for useful purposes by having plenty of surface in the parts of the furnaces where the heat may be absorbed, but a great deal goes up the flue and only serves a useful purpose in causing a draught, which draws in the air under the grate bars. When less heat is required, however, some air is drawn in above the fuel bed to cut down the action of air through the fuel and to fully

PLATE IV.

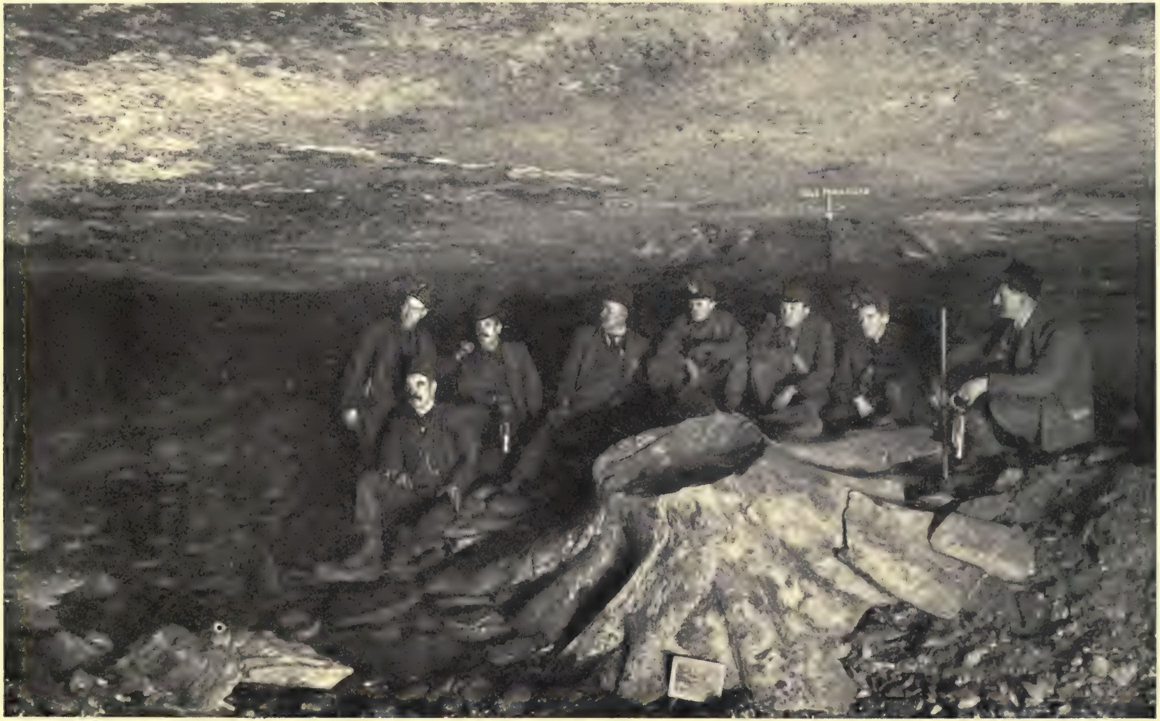

Photo by J. S. Horgan, Scranton.

Petrified tree stump, found in coal vein.

consume any gases that have distilled and not otherwise had enough air for combustion. Heat is lost by radiation at the grate bars and around the furnace or boiler. In well-arranged steam boilers or hot-water heaters, the water to be heated nearly surrounds the fire bed and the space above it, and in some cases, as in marine boilers, comes below the space under the grate bars, so as to take up any stray heat. To take up all the heat possible most boilers have a tubular surface filled with water in the path of the burning gases. Sufficient heat should be supplied to every room in a house, etc., to allow of a complete change of air twice an hour.

Everybody is acquainted with the fact that on a cloudy or rainy day fires do not draw well. This is due to low barometric pressure, which does not give sufficient difference in weight between a column of air, the height of the chimney, and this column of flue gases. On a clear day the hot flue gases are very much lighter than the outside air, and the weight of the atmosphere pushing at the grate bars causes an upward current in the chimney or a good draught. Wind causes a suction, as a rule, at the chimney top, and some contrivances assist in this matter, but most of them, especially those that revolve, become corroded by acid gases from coal tar and acid from burning wood and get out of order very easily. This suction effect is mechanical.

To obtain the most efficient service from a domestic heater, it is best to use coal of such size that the fire does not die out around the sides and produce an insulating layer. Then it is well to have a large body of glowing coals with little draught after the fire is well started. With a fire banked high in the centre and lower on the sides one gets the greatest amount of radiating surface from the fuel and exposes the sides in a hot-water or steam generator to hot gases rather than to ashes or to coal that is not burning. For economical reasons it is not well to rake the fire very thoroughly, as a layer of ashes on the grate bars acts as an insulation, and very little heat is radiated downward. One should be able to hold his hand under the grate bars with comfort, unless live coals have dropped in raking. Very few of these should be raked out, of course. Where there are water tubes or pipes, they should be cleaned of soot often, as that material is a good insulation in a bad place. All the insulation ought to be around the outside of the boiler and not inside.

Another method of creating heat is by mechanical means,—friction. A German physicist, Robert Mayer, found a value that constituted the mechanical equivalent of heat. Expenditure of mechanical forces always results in a definite amount of heat. *Friction* is the term given to the resistance to motion that causes heat. Sometimes mechanical force produces electricity, but this finally goes into heat. All force goes into a corresponding amount of heat, and all heat produces its equivalent in force, although it works in a roundabout way in nature by causing the growth of plants, thus producing grains and grass for animal consumption and, in time gone by and to some extent now, coal and oil. Any of this energy in coal or food that is not consumed to create work is still potential or stored energy. The fact is it would be hard to know how the total heat of the universe could change very much, as for any planet that was cooling off, another must be absorbing the heat in some way.

Heat moves in substances, as electricity does in wires. Heat flows through metals best, moderately well in water, and to a lesser extent in air. In water and air it moves chiefly by currents called convection currents. Some people think cold radiates; that a cold substance like a window-pane sends off cold. It seems to do so only by absorbing heat. For heat to move best in water or air, it must rise and circulate. It returns when cooled. Heat causes the particles of a body to vibrate more rapidly and this tends to cause a more fluid state. If one heats ice, water is obtained, which is fluid due to the mobility of its particles, and when heated still further all tendency to be held together is lost, as the motion of the particles overcomes all force of cohesion, and steam results. Iron becomes liquid and at a white heat it vaporizes. At the heat of the electric arc all known metals vaporize, and even carbon is slowly vaporized.

When ice melts it takes on a quantity of heat called *latent heat of fusion.* When it freezes again, this latent heat is given off, which slows down the freezing until this heat can be absorbed. There is thus a check on thawing and a check on freezing. If it were not for this, a lake or river would freeze to the bottom as soon as it began to freeze. Similarly, when water or any liquid is converted into a gas, there is absorbed quite a quantity of heat called *latent heat of vaporization.* Here again the wonderful provision of nature protects the food that is being cooked by not permitting all the boiling water to go into steam at once, but provides for so much heat being absorbed that it takes a relatively long time to boil off a quantity of water.

One of the most important conceptions in connection with heat is that of *insulation.* Our clothing is insulation to keep in heat, so are bedclothes and the walls of houses. The fur on animals, the feathers of birds, and the blubber of whales are for purposes of insulation or keeping in body heat. The way most of these substances act is by shutting in air in pockets so there are no currents. Thus air makes a good insulator or nonconductor. It is called *dead air* in these cases. Massive silica acts as a good conductor, but finely powdered silica is an insulator; finely powdered magnesia, asbestos, carbon, dry wood, and cork are good insulators because of the fine pores or dead-air spaces they contain.

When a person builds a house he should be informed of the possible insulating qualities of the walls, the down-stairs floors, the ceilings under the roof, etc., so as to have it warm and yet allow of the requisite fresh air to enter in cold weather without burning undue fuel. The writer has noticed the great difference in temperature on a very cold day on touching the outside wall in his kitchen (18 inches stone laid in deep mortar with 3 outside coats of plaster and inside laths and plaster) with one hand and the wall of the laundry with the other (which is of frame, although of good construction, with plaster outside and inside). The difference on a cold day was remarkable, and all in favor of the stone wall. There is not space here for figures on insulation, but abundant data may be found.

Other examples of insulation are noticed. In heating a pan containing water, the flame does not seem to touch the pan. In fact, it does not, but is so chilled that there is only a layer of cooled gases from the flame touching the pan, which tends to insulate it from the flame. The writer has often wondered why the same amount of gas in a quiet burner did not give the effective heat given by a blast lamp. The force of the blast drives away the insulating film and forces the hot flame right up to the object being heated. If a drop of water falls on a red-hot stove plate, it is seen to spin around rapidly, but remains for some time, while if the plate were only moderately hot, the water would flatten out and evaporate. This is called *spheroidal state,* and is caused by the insulating effect of the steam between the globule of water and the hot plate.

People are generally familiar with modern improvements in heating of houses and other buildings. Some of the larger recent improvements in the utilization of heat may be here referred to. Hundreds of thousands of horse-power used to go to waste in the shape of combustible gas from blast furnaces. Almost every one has seen large volumes of burning gases ejected from the tops of such furnaces when passing in a train or otherwise; and at night it has been a beautiful sight the way the whole neighborhood is illuminated by a red glow from this periodic occurrence. Now the manufacturers of iron are using these gases to create power in gas-engines and soon these works will be less picturesque at night, but all will benefit by the saving, as we do in all large manufacturing economies.

The greatest advance in heating has been in the electric furnaces that make graphite, calcium carbide, aluminum, tool steel, phosphorus, etc. Some of these furnaces use several thousand horse-power or kilowatts. A kilowatt is about one-third more power than a *horse-power.* The sources of electric power in this country are water power, anthracite coal waste or culm, blast-furnace gases, producer gas or coal-fired boilers.

At one time there was a very large piling up of fine siftings of anthracite coal, forming enormous culm piles. A large part of this former discard has of recent years been resieved and used as *buckwheat* and *rice grades* for use in steam boilers. For household use they have been impracticable, except with automatic feeding tubes in the furnaces or boilers, in which case their consumption has been possible. Under present conditions the amount of culm formed is not great, but, as it is, it lends itself to a new and useful industry,—that of the manufacture of coal briquettes (coalettes). Fuel in this form may be practically as good as in assorted sizes, as the binder *can* have burning properties itself, and the coal *may* hold together in lumps, practically until consumed. It is, of course, sold for less than the prices of domestic sizes to make it interesting to the householder.

There was a period in this country's history, that has in fact extended until about the beginning of this century, when there was very little attention given to saving materials, heat, power, or labor. The effort to save labor came first, especially as labor began to demand more compensation; then power was economized by putting in individual motors, economical boilers, water-power plants, etc. During the last decade there has been very constant effort to save waste materials or by-products, and much can yet be done. Probably what is most requisite now is a complete checking up by experts of all the factors of labor, machinery, waste materials, and power. It will require a chemical engineer of the best training and aptitude. He will be the final *efficiency engineer.*

Some time ago the writer's father read a paper on *Conservation in Chemistry,* in which he spoke of three periods in this country's history. The first he called Exploration, the second Exploitation, and the third he said was just dawning and called it Conservation.

CHAPTER VI

AIR, OXIDATION, AND VENTILATION

Air, or "the atmosphere," surrounds the earth as a gaseous covering which, because of its weight and compressibility, is densest at the surface and of vanishing quantity at distances of from 50 to 200 miles above the earth. It is so rare at 50 miles that it ceases to affect light rays.

It can be experimentally shown that air has weight by the use of a balance and in other ways. If a pipe, open at the bottom and dipping into water, be exhausted at its upper end through an opening and then the opening be closed, it will be seen that water rises to fill the place of the air extracted. It has been found that water will rise 34 feet in this way. As the lower end of the tube dips into water and the water in the vessel is exposed to the outside air, the weight of the atmosphere must just balance this column of water of about 34 feet in height. As mercury is many times heavier than water, it does not take as high a column of mercury to balance the pressure of the air; in fact, about 30 inches of mercury are as heavy as a column of water of 34 feet, or one of air as high as the atmosphere extends. Because of mercury making a more practical column to measure the atmospheric pressure than water, it is thus used in instruments known as barometers. The mercury barometer, in its simplest form, is a glass tube somewhat over 30 inches long and closed at one end. It is first filled with mercury and then inverted over a cup containing mercury. The mercury in the tube drops a little, leaving a vacuum at the top, and the distance between the top level and the mercury in the cup is equal to the pressure of the atmosphere, or about 30 inches (equal to 760 millimetres at the sea-level) on a clear day. In stormy weather it drops an inch or a little more, and at higher levels, such as in mountainous or plateau regions, it is less. This lowering of the barometric pressure allows of the boiling of water at lower temperatures than 212° F. (100° C.), and on very high mountains it boils as low as 180° F. This vacuum in the barometer tube is known as the Torricellian vacuum, after Torricelli, who was the first important investigator working on the properties of the air in the seventeenth century. Lavoisier and Cav-

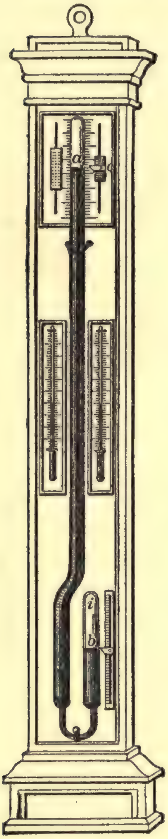

Fig. 2.—Mercury barometer.

endish, as we have seen, showed the true composition of the air in the latter part of the eighteenth century. Air is over 14 times as heavy as hydrogen, and water is 800 times as heavy as air.

Air is remarkably uniform in composition, due to the fact that plants are great feeders on carbon dioxide that people and lower animals produce in large quantities. Because we know a thing happens it can generally be explained. Wherever people are, there are plants to consume the human and animal output of carbon dioxide, but the plants fail to consume all that is in the air, as their decaying vegetation in largest part ferments or rots, giving off again what they have held for a season or for a longer period. There must at one time have been much larger quantities of carbon dioxide in the atmosphere, as a great deal of the surface and near surface rocks are carbonates, and now take very little part in the carbon dioxide cycle. When there was much more carbon dioxide in the air plants grew more profusely, as seems to have been the case in the coal age. The presence of carbon dioxide in the air can be demonstrated by blowing air through a tube into some clear lime water. The liquid at once becomes cloudy or milky, from carbon dioxide. The white deposit[1] that forms in the lime water that is purchased from the drug store, when it is uncorked a few times and kept a while, is due to this formation of calcium carbonate. Sometimes it is very important to ascertain whether air in wells, brewing vats, etc., is contaminated seriously with carbon dioxide. To test the matter a lighted candle is lowered before men venture in. If the candle is extinguished the air is certainly contaminated, and pure air must be introduced before it is safe to venture into such places.

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[1] $CaO_2H_2 + CO_2 = CaCO_3 + H_2O$.

The important constituents of the air occur in the following proportions:

	By volume	By weight
Nitrogen	78.06 per cent.	75.50 per cent.
Oxygen	21.00 per cent.	123.20 per cent.
Argon	0.91 per cent.	1.25 per cent.
Carbon dioxide	0.03 per cent.	0.05 per cent.

There is, in addition, a variable percentage of moisture, as vapor, in the air, and very small quantities of *helium, neon, krypton,* and *xenon.* Besides these elements there are nearly always in the air traces of hydrogen, ammonia, nitric and nitrous acids, ozone, sulphur gases, and organic impurities such as are supposed to be exhaled by people. The burning of coal gives off sulphur dioxide gas. It has been estimated that 1300 tons of sulphur dioxide pass into the atmosphere in New York City every day from the combustion of coal.

Nitrogen (N) is an inert gas, and its consideration includes argon, which was long unknown and included in all analyses with nitrogen, and, in fact, even now few investigators attempt to separate the two gases when they analyze air. The other recently discovered gases are small in amount, much like nitrogen, and have no special influence that we know of, although they may in time be found to perform some special functions. They may have come from the degradation of elements such as radium, some of which may no longer exist, at least near the earth's surface.

Water is a quite variable constituent of the air. When the air is saturated with water at any temperature, it is said to be at the dew-point, and the colder the air becomes, the more water is precipitated in nature, as rain. Warm currents of air can, of course, carry much more water than cold ones, and when a warm, moisture-ladened current of air encounters a colder one the cold area chills the warmer so that the moisture is thrown out as rain or snow. Rain is precipitation in warm or moderate weather. Snow is precipitation from clouds at a temperature below freezing. Water does not form, but the change is from the gaseous state direct to the solid or crystalline state. Because of the looseness of the crystalline structure it takes a great many inches of snow to form one inch of water on melting. Hail is first precipitated as water and forms in drops, which meet colder air strata, where they are frozen to the solid state. Dew is precipitation of moisture of the air in the lower strata, due to the lowering of the temperature at night. It condenses on grass, leaves, and other objects, because of the greater prevalence of moisture close to the ground than elsewhere.

The air may contain as much moisture that is invisible, showing a blue sky, at one time as it does at another when there are clouds. In the first case, however, the air must be warmer than in the second. Clouds form in a clear sky. They don't have to come from some other locality, and clouds may disappear into clear air or blue sky. When the air reaches the dew or precipitation point, clouds form, the water passing from the gaseous into the vapor state, and the opposite is true when they disappear. White smoke from a locomotive or power plant is moisture vapor, and, if the air is not very high in humidity, it is quickly absorbed into the gaseous (or invisible) state in the air. Humidity means the percentage of moisture in the air that it is capable of holding at that temperature. Humidity 60° means it has 60 per cent. of the water it can hold as gas at that temperature.

The amount of water that is required to saturate a cubic yard of air at different temperatures (Fahrenheit) is given herewith:

14°	26.8 grains	68°	206.5 grains
32°	58.6 grains	86°	362.1 grains
50°	112.6 grains	212°	1. lb. and 81 grains

One cubic mile of air saturated with moisture at 95° F. would give up 140,000 tons of water if cooled to

7000 grains = 1 lb avoirdupois.
437½ " = 1 oz "

32° F. The moisture ordinarily present in the air is shown by the condensation of water on the outside of a pitcher of ice-water, where it is precipitated by the chilling of the layer of air to its dew-point.

Air seems to be best for us when the moisture content is moderate. Outside air is rarely too dry, but often too humid. It seems to be purer and more exhilarating after a storm, unless in summer, when the heat may be intense and thus unpleasant. For instance, after a fall of snow in winter the air is moderately dry and bracing in most localities. In winter the heated air of the houses is too dry, especially in the Northwest, unless water is specially evaporated from pans on the radiators, etc. This is because the outside air, which contains enough moisture for its temperature, if heated and moisture is not supplied, is relatively so dry that it tends to parch the throat and air passages of people.

Ozone is caused by various organic changes and electrical action, and is soon consumed in oxidizing sulphurous acid from burning sulphur in coal and organic matter in process of decay. Ammonia and other nitrogenous gases are in the air in small quantities at times, and removed by the rain, which carries them into the soil, for which they are beneficial. Hydrogen sulphide is nearly always in the air in small amount, especially in houses. It comes from toilets and furnaces. This gas causes the tarnishing of silver and the darken-ing of white paints made from white lead. For outhouses and bath-rooms white paint made from zinc oxide is preferable, as it is not affected by sulphur gases. Besides the gases in the air, there are always certain amounts of dust and bacteria. Dust is deleterious to the lungs, but it is largely caught in the nasal passages in breathing. The purer the atmosphere is with regard to the dust the safer, and, as a rule, the outdoor air contains less dust, especially at night, than indoors. Dust in the air is made visible by a ray of sunlight. Air bacteria are practically harmless, as pathogenic organisms cannot live very long subjected to air and light and so are not found normally in the air.

By intense artificial cold air can be liquefied. When in the liquid state, freely exposed, it boils until all is vaporized, the nitrogen going off first, until the air is rich in oxygen (containing about 93 per cent.). Liquid air boils at about —347° F., while liquid carbon dioxide does not boil at so low a temperature, but at —112° F. If liquid air is kept in a vacuum, double-walled, glass bottle (it must not be corked or a violent explosion will ensue), it vaporizes slowly but surely. A little can be kept for about ten days in a vacuum, or so-called, Dewar flask. This liquid is so cold that it changes mercury when in contact with it into a solid so dense that it can be used as the head of a hammer with which to drive nails.

According to the nebular hypothesis, what is now our planet was once a mass of swirling hot gases, or rather the earth and other planets revolving around the sun constituted such a nebula. As these gases cooled, some condensed to liquids, which took spherical forms due to the rotary motion they had. Finally, these balls of hot liquid cooled, and one of them, this earth, formed a solid crust with gaseous covering, which is the air we have been describing. Most of the substances that went into this liquid condition and afterwards assumed solid form combined with oxygen to form oxides, such as iron oxide in iron ore, silicon oxide or silica, aluminum oxide or alumina, and elements combining with so much oxygen may account for there being much less oxygen in the air than nitrogen. Nitrogen, being very inert, did not go into combination. Many of the substances combined with oxygen, or in some cases sulphur (which acts like oxygen in many ways), have been freed from their combinations to make them more serviceable, and thus we have obtained the metals. If left exposed to the weather, most of these metals corrode, or oxidize, at least on the exposed surfaces. Sodium, potassium, calcium, and some other metals quickly combine with oxygen in the cold, and are thus converted into oxides. Other metals, such as aluminum, lead, zinc, and copper, oxidize on the surface only and the body of the metal is protected. Iron or steel does not corrode except at a red heat or where moisture is present. All these metals combine easily with oxygen at a high heat. The dross on lead when it is melted is oxide, and copper changes on oxidation to a black powdery substance. Most metals will burn brilliantly in oxygen if a little heat is applied to start reaction.

Besides the oxidation of metals, we have that of organic matter. This form of oxidation is called *combustion,* and is treated in Chapter V.

The purification of the air in buildings is one of great importance, and the subject is called *ventilation.* In summer this is not a problem to be considered, but in winter it is a live subject. Where open fireplaces are the means of heating houses, they take care of the ventilation automatically by creating such strong draughts that the fresh air from outside obtains an entrance. In cities, however, heating is not done to any extent by open fireplaces. Where the hot-air furnace is used ventilation is effected, but it is very difficult to supply the water this warmed air requires at the higher temperatures. If the outside air is at 32° F., it has only some percentage (according to its humidity, say 60 per cent.) of the possible water content at this temperature, or 58.6 grains (see p. 70), and if heated to 68° F. it should have the same percentage of the total amount of moisture possible at that temperature, or 206.5 grains per cubic yard. If this moisture is not supplied, it makes a seriously dry atmosphere to live in. One that ought to have, say, 60 per cent. of 206, or 123.6 grains, and only has 60 per cent. of 58.6, or 35.1 grains, or less than one-third, is palpably deficient in moisture. Water is supplied sometimes in hot-air heating, but the application is not usually effective.

Most installations for heating are, however, hot water or steam, especially large installations, and all the ventilating must be done specially. Inexpensive instruments, called *hygrometers,* to show the relative humidity, are of more importance than thermometers in the home.

The necessity for ventilating is the only part of this subject that seems to bear on chemistry, and there is quite a little difference of opinion among writers. The art of ventilating is an engineering matter. Some writers have held that the air becomes impure because of the carbon dioxide with which it becomes charged. Others have more recently held that it is not so much the carbon dioxide in the air, but the fact that the air becomes heated by the presence of people in a limited or confined space, and it is therefore less bracing, and shorter and less beneficial breaths are taken, due to the lack of exhilaration. The third view of the subject is that noxious gases called anthrotoxins are given off, which have really poisonous effects upon people breathing them in appreciable quantity.

It has been carefully figured out just how much air a person needs by first deciding what the limit of carbon dioxide in the air may be and then showing how much space per person there must be to produce this quantity. The estimation of carbon dioxide in more or less contaminated air is certainly a valuable indicator of contamination. By experience people have been able to say when the air was fresh or ventilation was needed, and a limit of six parts of carbon dioxide per 10,000 of air in excess of what the outside air contained, has been given as all that was permissible. It can be shown about how much air a person must have per hour to produce various degrees of contamination in a room.

Air supplied per adult per hour in cubic feet	Excess of CO_2 due to respiration per 10,000 by volume
1000	6
1200	5
1500	4
2000	3
3000	2

There are about four parts of carbon dioxide per 10,000 in the air of cities, and, therefore, one adult would double this amount in 1500 cubic feet of confined air in an hour. A room 12 x 12 by 10 feet high would contain nearly 1500 cubic feet of air. Of course, windows and doors are never air-tight, but there are devices called metal weather stripping on the market that make them nearly so, and where these are used there should be windows always open on the side of the house away from the wind. This creates a current out rather than in, and the house would naturally have minor ventilating openings on the side toward the wind.

The second hypothesis, in which the deleterious effect is supposed to be due to body heat, is hardly tenable at all times, as it seems unreasonable to the writer, who has often experienced the sensation of exhaustion in a crowded room and does not believe it was due to heat alone.

The third proposition is that irritating or depressing gases are given off from the lungs. What these may be would be hard to show, as they must be very small in amount. There is a great difference in the effect on the system between exhilarating air and oppressive air, even if they should be chemically about the same. The safest way is to ventilate frequently to attain an apparent freshness in the air, and to minimize the effect of toxins, which probably do exist. Some facts, without figures, with regard to ventilation may be given. The oxygen necessary for life is greatest in pure dry air in low altitudes. This ideal location is hard to find, as the air is drier away from the seacoast. Moisture must be given off in the air from the lungs, due to the chemical processes at work, and therefore the air we breathe should not be saturated with moisture on entering the lungs. Humid days in summer are oppressive because the moisture normally taken up cannot be properly expelled from the lungs. In rooms that are not well ventilated the exhaled moisture accumulates, and this is one of the reasons why such air becomes oppressive. It would also seem as if air nearly saturated with humidity might hold active deleterious bacteria longer than dry air, as desiccation kills bacteria. Certainly damp, muggy weather causes the spread of disease.

The amount of relative humidity of the air may be greater when cool than heated. In the first case it might be about 80 per cent., but if the air was very warm it should not be much over 50 per cent. humid. People go to high altitudes for the cure of lung diseases, probably as the lungs are expanded more by the rarefied air, but difficulty comes sometimes from the heart being unable to pump enough blood for more rapid breathing. Cool air is somewhat more satisfying than warm or temperate air, as it is denser and contains more oxygen. Getting air richer in oxygen may be and probably is one of the benefits of outdoor sleeping.

Bath-room hoppers should be ventilated by positive suction. A little examination will show that very few are ventilated in any way, as the "stack" running to the roof does not ventilate the hoppers of "body gases" due to the water trap between the two. A real ventilating hopper can be obtained and they are, I understand, installed in a few office buildings in Philadelphia.

When people learn to know the air as well as they do food or water, they may choose their places for vacation sojourning because of the known properties of the air. Places will have to be advertised more specifically as to the bracing qualities of the air. They will have to tell what is the average content of oxygen per cubic metre at, say, 70° F.; the average relative humidity, the average bacterial content, the percentages of carbon dioxide, nitrous and nitric oxide, ammonia, and ozone in the air, and, in short, deal in facts and not in fancies.

Ozone is produced by the rapid evaporation of water in the direct sunlight. A few weeks prior to this time of writing (March, 1914) the writer had an interesting experience. The snow covered the ground fairly completely, although it had been melting rapidly for several days. I noticed, one evening, a strong odor of ozone in the house and seemed to trace it to an open window in which the air was blowing. I felt I could not mistake the odor of ozone, as I have had an ozonizer for water purification in the laboratory for several years and smell ozone from it daily. The next morning I took the train to about one hundred miles west of Philadelphia and noticed the same odor on the way, due undoubtedly to the bright sun shining on the snow and quickly evaporating the water. One evening in April, when I again noticed the very pleasant indication of ozone in the air, I tested for its presence with filter paper saturated with solutions of potassium iodide and starch water. Ozone acts upon the potassium iodide with liberation of iodine, which has the property of turning starch to a violet color. A violet colorization was noticed on several pieces of this paper the next morning. This effect was very noticeable by me a few evenings in March and April, but not later in the season.

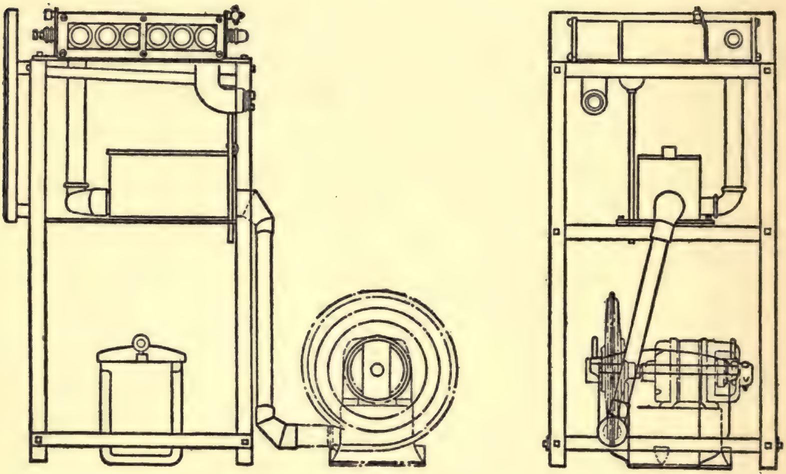

Fig. 3.—Air ozonator. High-voltage discharge tubes at top of stand. Blower at bottom.

Ozone is artificially produced from air by means of generators in which high-voltage currents discharge through glass plates or cylinders. In the dark one can see a blue-violet glow or so-called silent discharge in the ozonizer. The writer has found such ozonized air valuable in neutralizing escaping hydrogen sulphide gas in chemical manufacturing operations. The ozone generated should be strong enough to neutralize this gas but not enough to be very noticeable in itself. Ozonized air seems well adapted to use in churches and halls, although fresh, cool air in quantity should be preferable. Ozone certainly purifies the air from traces of organic matter, and it is claimed by some authorities, but denied by others, that bacteria in the air are killed by it. It is generally desirable to cool air artificially in crowded halls, even in winter time, as every person is at a temperature of 98.8° F. and when packed closely they will tend strongly towards raising the temperature.

CHAPTER VII

WATER

WATER is the most universally distributed and important substance we have. It permeates the universe, saturating the rocks and soil except at the very surface where the sun may partially dry things. Water may wet substances like sand, but it will pass off again if they are put in a warm dry place, or it may be chemically combined as water of constitution or crystallization. Gypsum contains water of this kind, and so it must be heated to a temperature above 212° F. to give up this water. It is then plaster of Paris, and it will set again in solid form when water is mixed with it. Portland cement also takes up water to form a hydrated composition, which operation constitutes a chemical change. Water is the chief substance in the vital fluids of animal and plant life, and our bodies are more than eighty per cent. water.

Water has such a simple chemical formula that people remember it when they cannot recall other chemical formulæ. It is formed by the union of two volumes of hydrogen and one of oxygen, making two volumes of water vapor.[1] Water is composed of eight parts, by weight, of oxygen to one part of hydrogen and is represented by the formula H_2O. Both of these elements are gases when uncombined. So it is easy to realize that their union produces a chemical change. If a grain of metallic sodium is dropped into a bowl of water, the elements forming the water by chemical union are separated. The oxygen goes to the sodium, forming sodium oxide, which unites with more water, forming sodium hydroxide or caustic soda (a base). Hydrogen gas is given off, accompanied by so much liberated heat that it frequently burns and forms water again with the oxygen of the air. If a cold metal plate is held above the flame of the burning hydrogen, the surface will become moistened from the water formed.

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[1] $2H_2 + O_2 = 2H_2O$.

Another interesting experiment consists in filling two volumes of hydrogen and one volume of oxygen into the same rubber bag, and then blowing soap bubbles with this gas, put under slight compression. These bubbles are lighter than air, due to the influence of hydrogen, the lightest known gas, and rise in the air. Just before they pass out of reach of the experimenter, they are lit by a taper and explode with considerable noise caused by the energetic union of the two gases with each other to form water.

Water is used as a standard for determining the relative weights of unit volumes of substances which we call specific gravity or density. Water, then, has a density of unity or 1.00. Alcohol is lighter and has a density of 0.785 when pure, and sand, which is heavier, has a specific gravity of about 2.5, iron 7.9, and mercury 13.6. All substances have a certain capacity for holding heat. It is a circumstance that water has the greatest such capacity, or, as we have seen before, *specific heat.* This property is made use of in water heating. If water did not have a large heat capacity it would not serve as an efficient means of distribution or storing of heat. In some fireless cookers a dish to be cooked is heated to the proper temperature and also a larger volume of water is heated to boiling and all is put in a well-insulated container. The water holds so much heat that it can give off enough to complete the cooking of a vegetable or cereal that has been heated only a very short time over direct fire.

There are a few other important points about water, ice (solidified water), and steam (gasified water). Water solidifies to form ice at 32° F. If heat is withdrawn from water the temperature falls until at 32° F., and although the surroundings are below 32° F., the temperature remains constant until all the water is frozen. Of course, when once frozen, the ice will become colder in accordance with the temperature of the air. One peculiarity of water on freezing is that it expands in volume and its density is diminished by about 6 per cent. The importance of this to the householder and others is that water must not be left in pipes exposed to freezing conditions, for the force of the expansion is great enough to burst iron pipes. Large pipes are not so apt to burst as small ones, as ice is not a good conductor of heat, and, after a coating forms on the inside of the pipes, the rest of the water can flow back upon the city pressure.

Water boils forming steam at 212° F. at the normal pressure of the atmosphere, or 29.9 inches of mercury (760 millimetres). When heat is applied the temperature rises until 212° F. is reached and then remains constant until the water is all converted into steam. This means that when water is boiling slowly it is just as hot as when boiling rapidly. If this fact were realized in the kitchen much fuel would be saved. The most suitable conditions for removing water or drying things are to have heat and means of conducting off the steam or vapor. Only moderate heat or warmth is requisite for water loosely held and with plenty of surface exposed; the other requisite is a current of air or other means, such as vacuum, to remove the water vapor. If water is the chief component, as in a solution, higher heat is desirable and ventilation is secondary in importance. The condition of the atmosphere often plays an important part in drying, for with a high humidity (the air charged with moisture) drying is less readily effected than with a low humidity.

Absolutely pure water is not a conductor of electricity, but the slighest impurity gives it some conductivity, so that all natural waters are moderately good electrical conductors. Dry wood is an insulator. A tree attracts lightning because of the water in the sap. Water dissolves many substances, such as many salts (besides common salt), sugars, gums, most acid and all alkaline substances. It mixes with or dissolves alcohol and glycerin; these when taken alone are solvents for some things that water cannot dissolve, but other solvents, such as gasolene, benzol, chloroform, carbon tetrachloride, carbon disulphide, and ether, are not dissolved by water to any very appreciable extent and are called immiscible solvents; in most cases they dissolve substances not affected by water.

What has been said above relates to pure water. Natural waters are not quite pure, as they have some substances in solution. In most cases the matter in solution is not great in quantity but it has a considerable effect in sanitary engineering. The impurities are generally measured in parts per hundred thousand or million, or in grains per gallon. A good water will have less than five hundred parts per million, or twenty-nine grains per U. S. gallon of solid matter. The author has analyzed a natural water with solids as low as seven-tenths of a grain per U. S. gallon, but natural waters with as little as a grain per gallon are rare.

The solids consist of inorganic matter, such as sulphates, carbonates, and chlorides of calcium, magnesium, sodium, and potassium, and generally a smaller amount of organic matter. The organic matter may come from leaf mould or other vegetable matter, and in cases of contamination from animal matter (sewage contamination). Of course, the presence of the latter in water is sufficient to condemn it for potable use. Artesian well waters are usually free from organic contamination, and so are deep spring waters, but surface waters are likely to be more or less contaminated and they are not much used for municipal supply without some form of purification.

Those who have not studied chemistry would have difficulty in understanding a chemist's report on a water, in spite of his efforts to be non-technical. Many people, however, are from time to time interested in ascertaining the purity of a spring or well water. There is a prevailing impression that a sparkling spring water must be absolutely pure and safe. This is no criterion, as a sparkling water may be dangerous and a turbid water may be perfectly safe. A water may be undesirable because of a disagreeable odor, turbid condition, a taste of iron, excessive temporary hardness, excessive permanent hardness, discoloration, excessive saline matter, etc. A water may be unsafe because of pathogenic bacteria. Of course, a very hard water may be unsafe for people subject to rheumatism, etc., but there is just one thing that ordinarily makes a water unsafe, and that is the presence of disease-producing bacteria, and probably the one most likely to cause trouble in water is *Bacillus* (B.) *typhosus.*

Most waters that are condemned by chemists are not criticised because *B. typhosus* is found, but because of the finding of elements that indicate sewage contamination. These substances themselves are practically harmless, but if water shows appreciable quantities of sewage admixture it is always unsafe even if *B. typhosus* is not found in a sample. For instance: albuminoid ammonia indicates nitrogenous matter; free ammonia indicates partially oxidized nitrogenous matter; nitrites indicate a further state of change, and nitrates indicate a final state of change from the original protein or nitrogenous matter coming from animal decomposition.

Quantities of the first three substances indicate more or less recent contamination, while the last-mentioned may mean that the organic matter is so fully oxidized that bacteria which accompanied the original nitrogenous matter must have been killed by the oxidizing influences, as pathogenic organisms do not live long where the oxidizing action of the air, especially in the sunlight, has full play. Besides these nitrogenous substances, chlorides and phosphates, especially the latter, indicate contamination from sewage.

In addition to these chemical tests there are some

PLATE V.

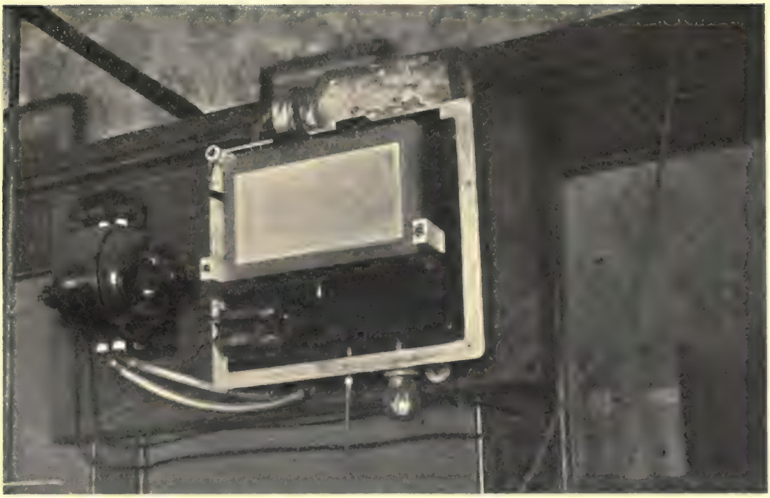

Photo by the Author.

Electric water ozonizer, showing glass plates with tinfoil surfaces.

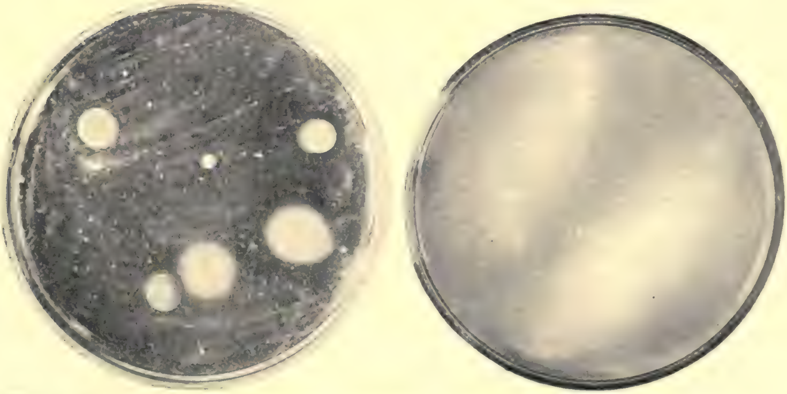

Photo by the Author.

Petri dishes, showing method of counting bacteria in water. Sample on left contaminated; on right, sterile.

bacteriological ones that may be briefly considered. The total bacteria in a unit volume of water (1 cubic centimetre, or c.c.) are counted under standard conditions: sometimes the test is made at ordinary temperatures, about 70° F. (20° C.), and sometimes the test is made at blood heat, 98° F. (38° C.). A bacteriological test that is often made is a specific test for the colon bacillus. While *B. coli* are not very dangerous themselves, they are nevertheless always in the human intestinal tract, from which they derive the name colon, and where they are found *B. typhosus* may also be found, and one would be taking undue chance in using such a water.

The bacteria are counted in an ingenious way. They are too small to be counted singly with proper accuracy in any unit volume, even with a high-power microscope, so a solution is made with nutrient material, such as beef broth and peptone, and enough pure gelatin so that it becomes a solid jelly when cold. This nutrient gelatin is sterilized and kept in tubes plugged with sterile cotton. When a little water to be tested is mixed with this nutrient solution after warming slightly and spreading out in a flat glass sterilized dish (called a Petri dish) and kept covered at the right temperature, each bacterium grows by a process of subdivision until there is a big family or colony where each one was in the medium before it was chilled. When the jelly is stiff they grow *en masse,* and these colonies can be counted in a couple of days by the unaided eye. When the test is made at 98° F. a gelatinous substance called agar or agar-agar is used instead of gelatin, as it will keep the broth stiff even at this rather elevated temperature.

If a water is found to have *B. coli* present, it should be condemned. Very many of any kind of bacteria, say, over 200 to 500, depending upon the source, and when the test is made at blood heat, any which produce acid, throw suspicion upon the water. These rather technical points are gone into briefly because people must be interested in the water they drink, and circulars and folders of water companies and summer hotels generally contain analyses of water from their particular springs, etc.

Some waters show a little radio-activity, but the influence of such waters is not well known at present, and we do know that an abundance of pure ordinary water is very beneficial, and radio-active waters might as well be left alone until a definite beneficial effect is established.

Many waters are celebrated as curative waters because they are carbonated, chalybeate, saline or alkaline, magnesian, etc., but the probability is that in most cases where cures are effected it is because of the quantity of water drunk, the times when taken, the air, exercise, and general stimulating effect of the active outdoor life or prescribed routine at these famous springs.

But resorts at the seashore where the water is known to be pure and where ozone is in abundance in the air, or the mountains for those who prefer them, are extremely effective places for those who cannot cross the ocean to go to some world-famous mineral-spring resort. The effect of drinking an abundance of water is essentially a cleansing one. Before eating, it clears out and washes the stomach. At any time taken, water dilutes the blood so that it can carry off all the waste nitrogenous matter, such as uric acid, which is not very soluble. So, logically, an abundance of water is needed fully to remove waste from the system.

We have referred to temporarily hard water and permanently hard water. *Temporary hardness* [2] is due to calcium bicarbonate in solution, and when the water is heated it is deposited as a sediment of calcium carbonate. Generally there are both kinds of hardness, and boiling alone does not throw out the substances causing the *permanent hardness*. If, in addition to boiling the water, a *little* sodium carbonate or washing soda be added to the water while boiling, the water is rendered perfectly soft. This permanent hardness [3] is due to calcium sulphate (sulphate of lime), magnesium sulphate, calcium or magnesium chlorides, any or all of them.

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[2] Reaction of softening temporarily hard water: $CaH_2(CO_3)_2 + \text{heat} = CaCO_3 + H_2O + CO_2$.

[3] Reaction for removal of calcium sulphate by means of soda: $CaSO_4 + Na_2CO_3 = Na_2SO_4 + CaCO_3$.

It does not matter whether it is in the domestic boiler or one in the factory, the happenings are about the same. The only difference is that better precautions can be taken to remedy matters on a large scale, as in factory operations. In the home calcium carbonate is freed in the water-back of the stove or gas heater and deposited in the boiler. The permanent hardness remains. In the factory sodium carbonate may be added (called soda ash, technically) to remove the permanent hardness, and, instead of having a deposit in the boiler where steam is generated, the deposit forms in a preheater, where it is filtered off. In the home a good deal of the deposit that forms in the boiler could be drawn off from a spigot at the bottom of the boiler, from time to time, but how many people know the purpose of the spigot?

When it comes to washing, water can easily be softened by the use of washing soda, or, better, soda ash, if it can be had, as it is an easily handled powder and is cheaper for what it does than washing soda. This effect, it seems to the author, was better understood a generation ago than now. At present many people will use a soap powder in preference to washing soda or borax.[4]

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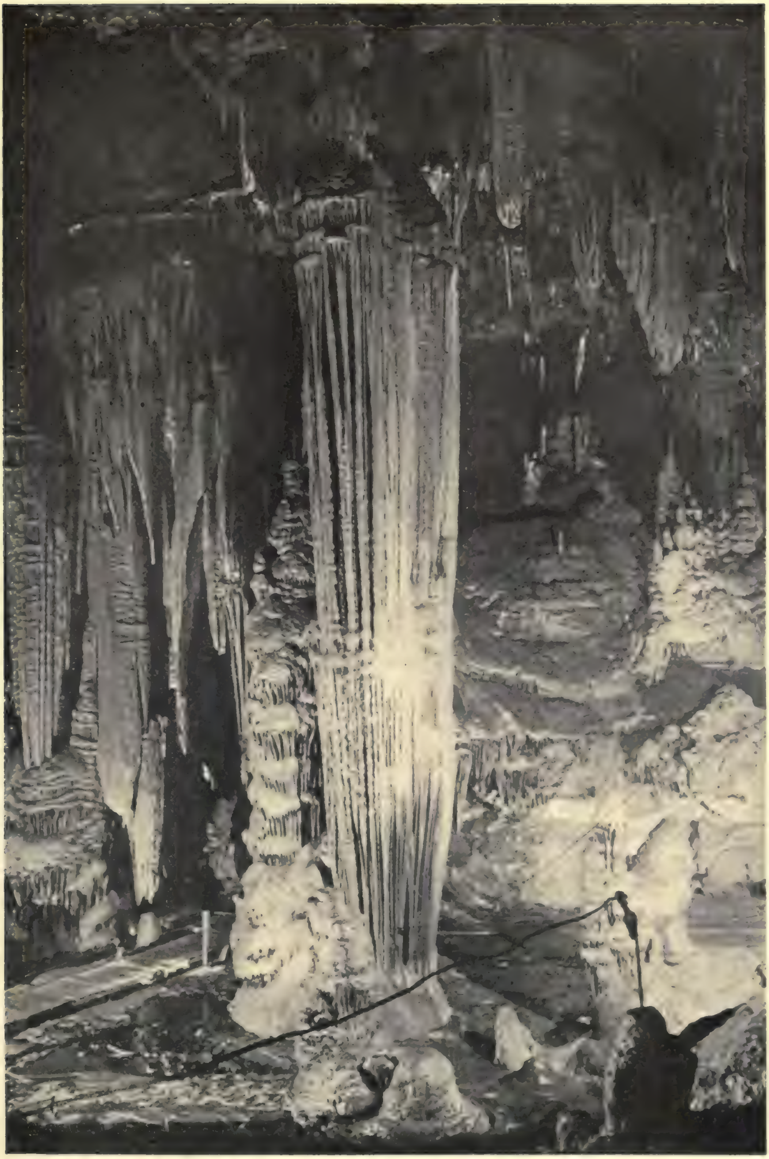
[4] Softening with borax is very much like that with washing soda:

$$\begin{array}{ccccccc} \text{Borax} & & \text{Calcium sulphate} & & \text{Sodium sulphate} & & \text{Calcium borate} \\ Na_2B_4O_7 & + & CaSO_4 & = & Na_2SO_4 & + & CaB_4O_7 \end{array}$$

PLATE VI.



Courtesy of Williams, Brown & Earle.

Beautiful effect in Luray Cave due to calcium carbonate separated from bicarbonate solution.

A soap powder is a mixture of soap and soda ash, and a very poor soap is apt to be used. It would seem the more rational procedure to soften a tub of water first with a few spoonfuls of washing soda, so that it readily makes good suds, and then to use the preferred kind of soap.

Water is purified for municipalities largely by sand filtration. The sand is graded with coarse at the bottom and running to fine at the top. The water is forced slowly downward from the top, and the fine sand catches not only suspended matter but bacteria as well, by some process of attraction possessed by the bacteria for sand. It may be such an attraction as that of rocks and oyster spawn, due to the glutinous character of the latter. At all events it happens, and if properly managed and not overworked such filters produce a safe water. Fortunately, the dangerous bacteria are killed easier than the others, so it is not necessary to remove all to make the water good. If a natural water contained from 1000 to 10,000 bacteria per c.c., it might be said that a filter would be satisfactory if it reduced the number to 25 or 50 per c.c.

In many places the normal supply is subject to some doubt, and so it is frequently necessary to purify the water in the home. One can boil the water and cool it, which renders it pure, and if stood to cool in stoneware jars it will in a day's time, or thereabout, take up fresh oxygen to replace what was lost in boiling, and be palatable. It can be distilled and aërated by cooling under proper conditions. The most practical ways are ozonizing and treatment with ultra-violet light. An ozonizer is shown on Plate V, and a line drawing of the latter in Fig. 3. The active effect comes from a mercury vapor lamp to which the current runs from binding posts *C* and *D*.

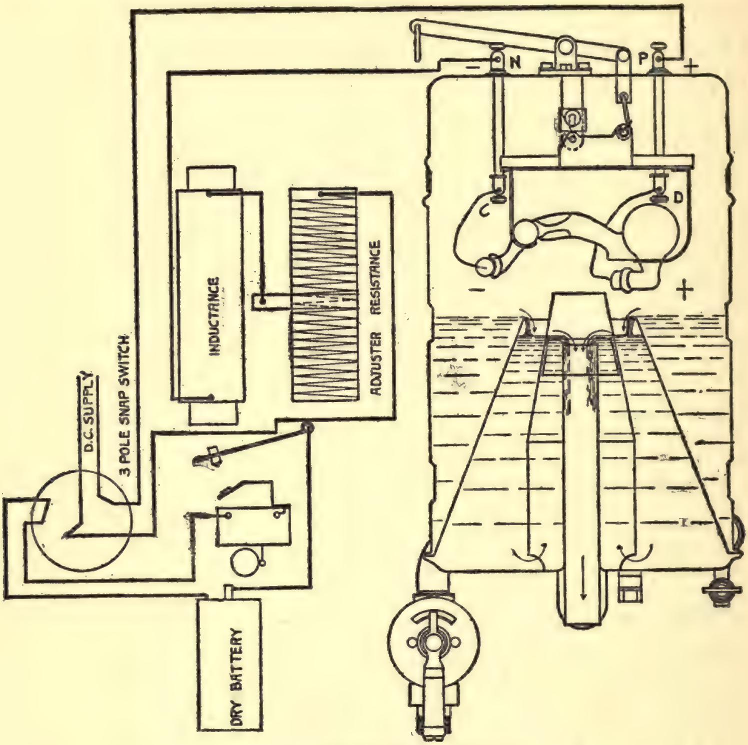


FIG. 4.—Ultra-violet water sterilizer.

Domestic sand and charcoal filters are not very reliable, as they cannot be kept in perfect order. There is another way, but too slow to be practicable, and it might not work in the hands of people who could not check up the purity of the water by tests. The Bible speaks of putting water in stone jars, "after the manner of purifying of the Jews." The author years ago while yachting had experience in purifying on a small scale the worst kind of river water (the Delaware water below Philadelphia) by simply putting it into a wooden cask and leaving it in the sun. In two weeks' time it was pure and sweet, although it had gone through a foul stage in the meantime. The bacterial life had gone on until the organic food had become exhausted, and then, of course, the bacteria died as people would if they had no food for a period. This method might not work in winter or would take much longer. It should not be tried unless the water so treated were tested, or unless the foul stage was noticed as intermediary and plenty of time was allowed to elapse after it.

Fresh waters consist essentially of (a) rain water, (b) waters of rivers and lakes, (c) waters from springs and shallow wells, (d) artesian-well waters.

Rain water is nature's distilled water, and contains only small amounts of nitrates, ammonia salts, carbon dioxide, etc., taken up from the air. It usually contains from 3 to 6 parts of solids per 100,000.

Surface waters vary greatly. In regions where the rock is silicious solids may be as low as 4 parts per 100,000, while in limestone regions, especially where the water has taken up acid from mine waters, it should not contain more than 50 parts. River waters become much polluted with organic matter and we have mentioned the indications of such character. It is highly desirable that cities and towns should all treat their sewage, and all counties should insist upon proper cesspools, such as are described on page 257, or better. Springs vary as much as rivers in mineral contents, although, as a rule, these are less. The waters are free from organic contamination only when isolated and free from any infiltrations from household sewage and barnyards. Waters from below the rock strata are pure, but are apt to run high in mineral matter. When they run above 50 or 60 parts of mineral matter per 100,000, they are not suitable for domestic use nor for boiler purposes. They often contain dissolved iron, which is removed as reddish flocculent matter on aëration.

Sea water contains about 3500 parts of solids per 100,000. A typical analysis of sea water is as follows:

Sodium chloride	2706	Potassium chloride	77
Magnesium chloride	367	Calcium carbonate	3
Magnesium sulphate	230	Magnesium bromide	3
Calcium sulphate	141		

A brief statement of the most important classes of *mineral waters* may be of interest, as they often prove of value medicinally.

Carbonated waters are saline and contain bicarbonates and free carbon dioxide.

Alkaline waters contain free sodium carbonate and bicarbonate.

Magnesium waters have predominantly magnesium sulphate and bicarbonate. They are purgative in their action.

Chalybeate waters contain salts of iron, especially the bicarbonate, which decomposes and precipitates ferric hydroxide on standing or aëration.

Calcic or hard waters are rich in lime salts. Most waters are more or less hard.

Sulphur waters contain hydrogen sulphide in solution and also sulphides.

CHAPTER VIII

ALKALIES AND SALTS

In the present section we will treat of alkalies and their combinations with acids, called salts. The metals producing these alkalies—namely, lithium, sodium, and potassium—uncombined, are not stable in the air; therefore, they are not used by themselves, so only a bare mention need be made of them. Alkali metals form the strongest bases because of their affinities for acids or acid radicles. Most of the salts, however, are well known, but the few that are not known to the lay reader will be worth giving the attention here suggested, as the effort is made not to dwell on substances of little interest more than enough to connect up the more important elements.

Lithium is used only in medicine, as a specific for rheumatism, as its salts are solvents for uric acid.

Sodium in combination is one of the most commonly occurring elements. When the word sodium is used it may mean the metal itself or it may refer, as in this particular case, to the metal in combination. In nature it is always found in combination and generally as chloride or common salt. The *metal,* sodium, is made at Niagara Falls by electrolysis and is used in the manufacture of some chemicals. It can be kept only under kerosene, as water attacks it violently, and so does air. A small piece dropped into water melts and assumes a spherical shape, rolls around on the surface violently, giving off hydrogen, which frequently burns because of the heat of reaction with the water. The net result is water containing sodium hydroxide, which has an alkaline reaction.[1]

Sodium hydroxide is used largely for soap-making and neutralizing acids, as in refining vegetable and mineral oils. It is shipped in hermetically sealed thin sheet-steel drums, into which it is cast whilst hot and molten, and the drum must be cut away and the mass broken up to use it. It is corrosive to the skin, and the fine dust made when it is broken up or emptied in a dry state from one container to another is very irritating to the nostrils; consequently, workmen handling it must wear gloves and aspirators with moistened sponges to intercept the particles. When sodium hydroxide (lye) is used in hot solution to open drains or pipes, it is effective by its saponifying action on fats. The mere addition of this material to water causes a heating up of the solution.

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[1] $\underset{\text{Sodium}}{2Na} + \underset{\text{Water}}{2H_2O} = \underset{\substack{\text{Sodium}\\ \text{hydroxide}}}{2NaOH} + \underset{\text{Hydrogen}}{H_2}$

Sodium hydroxide or common lye is made from salt in different ways, especially by electrolysis.[2] The chlorine that escapes may be led into slaked lime, when *bleaching powder* is produced. This substance is used in the home and factory for whitening wood pulp, cotton, or linen. Bleaching powder is now put up in metal cans holding a pound each, with sifting tops, and explicit directions are given for bleaching goods, including the use of washing soda with the bleach to make Labarraque's solution, or sodium hypochlorite. Straw for hats and braids is generally bleached with hydrogen dioxide solutions at moderately elevated temperatures.

Sodium compounds are not usually colored or interesting in any way except that they are very useful, which makes it desirable to give this space to them. They are invariably soluble, except when combined as complex silicates, such as feldspar or glass. The important compounds of sodium which are much used in manufacturing, in the household, and in medicine, are as follows:

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[2] $$\underset{\substack{\text{Sodium chloride}\\\text{(salt)}}}{2NaCl} + \text{(electricity)} + \underset{\text{Water}}{H_2O} = \underset{\substack{\text{Sodium hy-}\\\text{droxide}}}{2NaOH} + \underset{\text{Chlorine}}{Cl_2} + \underset{\text{Hydrogen}}{H_2}$$

Name	Formula	Use
Salt	$NaCl$	Condiment and to make chemicals.
Sodium hydroxide (caustic soda or lye)	$NaOH$	To make soap and chemicals.
Sodium carbonate (soda ash, sal soda, soda crystals)	Na_2CO_3	Cleaning, soap powders, scouring, and chemical purposes.
Acid sodium carbonate (sodium bicarbonate, saleratus)	$NaHCO_3$	Baking powders, etc.
Sodium sulphate (Glauber's salt)	$Na_2SO_4 . H_2O$	Glass-making and wood pulp.
Sodium phosphate (normal)	Na_2HPO_4	Medicine
Trisodium phosphate	Na_3PO_4	Water softening.
Sodium dichromate	$Na_2Cr_2O_7$	Tanning.
Sodium thiosulphate (sodium hyposulphite)	$Na_2S_2O_3$	Tanning and photography.
Sodium nitrate	$NaNO_3$	Agriculture and chemicals.
Sodium borate (borax)	$Na_2B_4O_7$	Cleaning and use as mild alkali.
Sodium silicate	Na_2SiO_3	Soap filling, silk dyeing, etc.
Sodium chlorate	$NaClO_3$	Pyrotechnics, explosives and textile work.
Sodium peroxide	Na_2O_2	Bleaching.

Some people confuse the two carbonates of sodium, the ordinary carbonate (Na_2CO_3), known among chemists as sodium carbonate, among manufacturers as soda ash, and in the household as washing soda, with the bicarbonate. When fully crystallized with water sodium carbonate is much diluted, as it has ten molecules of water, $Na_2CO_3 . 10H_2O$. The compound gives off water easily on standing uncovered, changing from moist crystals to dry powder which still has one molecule of water. The molecular weight in the first case is about 106 and in the second case 186. Sodium carbonate is sold now as monohydrate with a molecular weight of 124. It is easy to see that dry soda is cheaper than the crystals at anything like the same price. Sodium bicarbonate ($NaHCO_3$) has only one-half of the hydrogen of carbonic acid (H_2CO_3) neutralized, and has twice as much CO_2 gas that it may give off as the normal sodium carbonate based on the sodium in combination. This is why it is used in baking. There would be less soda salt left in the cake, etc., when it is neutralized with acid than if washing soda were used. Sodium bicarbonate is sometimes known as saleratus as well as baking soda.

An interesting development in making alkali and alkali-earth nitrates has been their manufacture from air under the influence of an electric arc or spark from platinum points. The manufacture was first started at Niagara Falls, but did not succeed, due to poor contact of the electric arcs with the air and consequently low efficiency and waste of power. This was in spite of the use of comparatively cheap electrical power. (The writer has been told that power at Niagara Falls costs about \$20–\$22 per horse-power per year, and at places in Norway \$9–\$10). An improved process invented by Birkeland and Eyde was located in Norway, and is making large quantities of nitrate of lime for agricultural purposes and other products. To show the result of efficiency in chemical engineering, as the first process tested at Niagara Falls did not pay, Birkeland and Eyde extended the arcs by means of electromagnets, and in that way secured more surface to the arc and more contact with air, with consequent greater production of nitric acid. It has been stated that about 120,000 tons of nitrate and nitric products are produced per year in Norway. A nice contribution to industry.

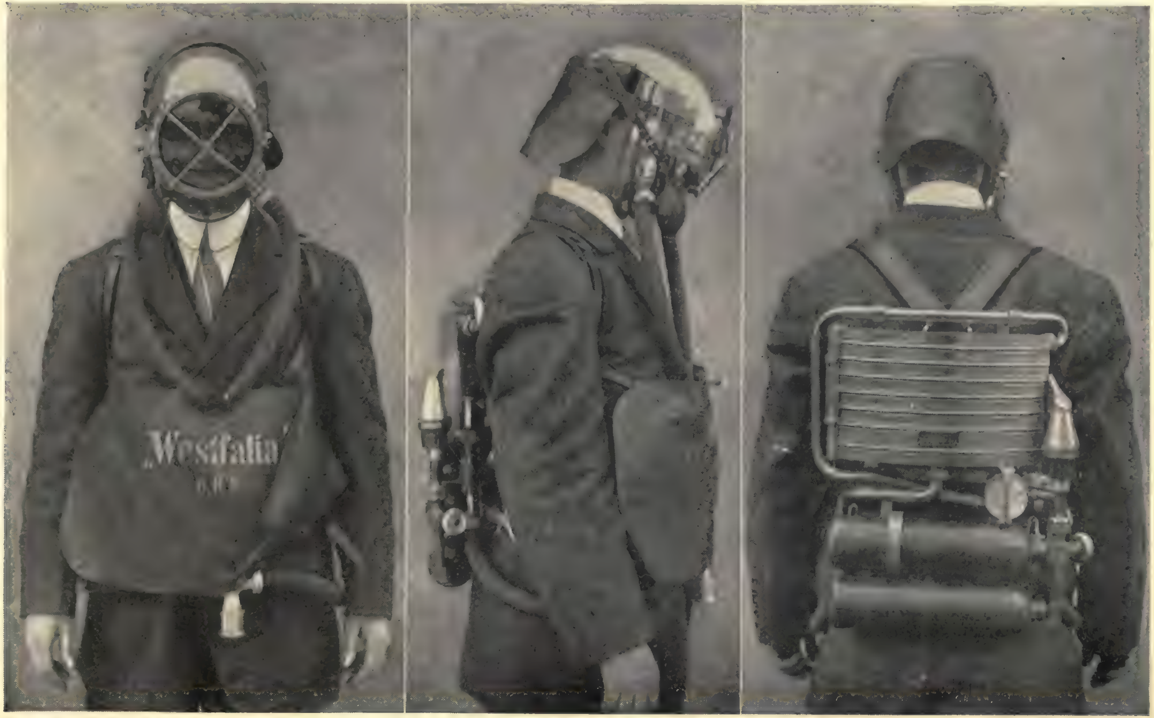
Of course, vast quantities of nitric acid in the aggregate are produced in nature by lightning and are carried into the soil by the rain. Doubtless nature still produces more by electric sparks than man does, and both serve the same purpose of stimulating vegetable growth.

Potassium in the metallic state is very much like sodium, and its alkaline compounds and salts are also quite like the corresponding sodium compounds. Potassium salts are in many cases less soluble and less deliquescent (or water absorptive). For instance, potassium nitrate can be used, along with sulphur and charcoal, for making gunpowder, as it does not absorb water on mere exposure to the air, and for the same reason potassium chlorate is used for match compositions, rather than sodium chlorate. The great value of potassium salts, or "potash," as they are sometimes called in commerce, lies in the necessity for their use in agriculture. Potash is supplied naturally from the weathering of feldspar, as seen in Chapter XII.

The chief commercial sources of potassium salts are the great saline deposits at Stassfurt, Germany. Potassium chloride is the chief commercial salt, and most other potassium salts are made from it. Natural saline lakes in the arid regions of Western United States are likely to prove a strong competitor to German potash, as the salt seems to occur, with other substances mentioned on page 112, in almost unlimited quantities. Seaweed and feldspar have been cited as sources of commercial potash, but the expense of extracting it from these materials would seem to be greater than obtaining it from these saline deposits, which will furnish other valuable chemical substances at the same time. One can distinguish potassium from ordinary salts by putting a little in a blue flame of a gas stove or alcohol lamp. Potassium colors it violet, while sodium makes it yellow. If the two are mixed one must view the flame through blue glass, which cuts out the yellow light, as yellow and blue are complementary colors (see page 34).

Ammonium compounds are surprising substances. We realize this even when we have known about them for a long time. Why nitrogen when combined with hydrogen (NH_4) should act just like a metal, in that it goes into combination and comes out of it intact,

PLATE VII.



Courtesy of American Museum of Safety.

Views of respiration helmet.

is a strange circumstance. It is almost enough to make one believe that other metals are composite. But there are other reasons coming up of late which indicate to us that metals as we know them are not necessarily indivisible (see Radium, page 140 *et seq.*).

Probably the chief value of ammonia lies in the use of the dry gas in ice-making. When the gas is compressed, heat is given off and this heat is absorbed by running water. In the next cycle of the process the gas is suddenly released from its compressed state, and absorbs large quantities of heat (creates intense cold), which effect is communicated to other places by means of a brine, such as salt, calcium chloride, or magnesium chloride solutions. These solutions remain liquid far below the freezing point of ordinary water. Instead of compressing ammonia gas to a liquid, ammonium nitrate has been recently found useful in condensing it, and the gas is given off on heating slightly. Ammonia is also valuable for household cleaning in very dilute solution, in the chemical laboratory as a mild alkali to neutralize acids, and as ammonium sulphate in agriculture. The danger of handling tanks of compressed ammonia is very real, as they may break from flaws or careless handling, such as being placed where it is too hot. Escaping ammonia gas will overcome and kill those near who cannot quickly escape to the outside air or be rescued by some one with a respiration helmet to supply the rescuer air for breathing while he lends aid to whomever is overcome. This helmet, views of which are shown opposite page 104, is also used in coal mines and wherever stifling and deadly gas must be encountered.

For agricultural purposes large amounts of nitrogen in some form must be added to the soil, as is referred to in Chapter XII. As an alternative of sodium nitrate, from natural deposits in Chili, where several million tons per year are produced, and calcium nitrate (air saltpetre), made in Norway from the oxidation of the nitrogen of the air by means of the electric arc, we can use ammonia salts if their price is competitive. About 1,000,000 tons per year of nitrogen in this form are produced each year from the coking of coal and used largely in agriculture. But even this is not enough for the great and growing demand. It has recently been found by Dr. Haber and the Badische Aniline und Soda Fabrik of Ludwigshafen am Rhein, Germany, that ammonia can be produced economically by the interaction of nitrogen of the air and hydrogen under great pressure at an elevated temperature and in the presence of a catalytic substance, such as iron oxide. Certainly science does not ignore the tiller of the soil, who in fact owes a great debt to the chemist. The Badische Company have prepared themselves to make 130,000 tons of ammonium sulphate a year.

We now come to the *alkaline-earth* compounds. They were called by that name before chemistry was a well-developed science because the oxides were supposed to resemble some form of earth or clay. These substances are important to us because lime is a member of this family and we do so much with lime (calcium).

Calcium is the best-known member of this family, and occurs native (in combination) as limestone, chalk, whiting, coral, etc., which are all composed of calcium carbonate ($CaCO_3$). The free metal calcium itself has been made only in a small way. It looks like metallic sodium. It must be kept under an hydrocarbon oil to preserve it from oxidation. All skeletons of mammalia are made up of calcium phosphate, and large deposits of phosphate rock are found which show indications of skeletons of prehistoric animals. This material is used for agricultural purposes and as a source of phosphorus for matches and alloys. This is one of the many evidences of how nothing is lost in nature. Much of this same phosphorus and lime may serve as the skeletons and elements of the tissues of successive generations of mammals.

Burned limestone, or quicklime, is used for so many purposes that are well known, such as making mortar, that extended treatment of the subject is unnecessary. Much of the lime used for mortar contains magnesia. This weakens the mortar, but does not necessarily affect it seriously for masonry. For fine, indoor plastering, it should be made from pure lime. In Portland cement manufacture, magnesia is particularly detrimental. Lime when saturated with chlorine forms bleaching powder, and when in good fresh condition should contain 35 per cent. of chlorine available for bleaching. Lime at a dazzling white heat, when fused in the electric furnace with coke, makes calcium carbide. When water is added to calcium carbide,[3] acetylene gas is given off, which burns brilliantly and is used for isolated lighting plants, automobile headlights, and for oxy-acetylene welding. Calcium fluoride is a naturally occurring compound in beautiful yellow or violet crystals. Hydrofluoric acid is the gas that attacks and etches glass. We have yet to mention the useful compound of calcium, *calcium sulphate,* which occurs naturally as crystalline gypsum. When gypsum is heated it loses water of crystallization and becomes a powder called plaster of Paris.[4] In certain massive forms gypsum is called *alabaster* and has been used in carving very fine pieces of sculpture or statuettes.

Having taken up the most important alkaline earth fairly fully, we will not have to dwell so long on the others. *Barium* is found chiefly as barium sulphate, or barytes, and used considerably in a levigated condition for addition to white paint. It is also made into sulphide by heating with charcoal. This sulphide is phosphorescent if kept in a closed tube, and gives off light in the dark if it has been previously exposed to direct sunlight. Barium carbonate is found as an ore and, on heating strongly, gives off carbon dioxide as lime does. Thus, barium oxide has the property of taking on excess of oxygen from the air at a certain temperature, forming dioxide, which gives off the extra oxygen at a certain higher temperature. This is used as a means of making oxygen. Barium dioxide when treated with sulphuric acid forms a valuable solution,—namely, *hydrogen dioxide;* the by-product is barium sulphate, which can be used as a paint pigment or can be converted, by several successive processes, into barium oxide again. Barium compounds, especially the nitrate, give a very vivid green color to flame. This is used in fireworks, etc. Barium hydroxide has been used as a water softener.

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[3] $CaC_2 + H_2O = CaO + C_2H_2$.

[4] $CaSO_4 . 2H_2O + \text{heat} = CaSO_4 . \frac{1}{2}H_2O + 1\frac{1}{2}H_2O$.

The chief interest attached to *strontium compounds* is in the use of the hydroxide in *refining beet sugar,* as it forms a compound with sugar called *strontium saccharate,* which enables one to separate the pure sugar from the beet-root molasses, and sugar is subsequently freed from the strontium by means of carbon dioxide.

The strontium carbonate so formed is converted again into strontium hydroxide by means of superheated steam.

Magnesium resembles the alkaline-earth metals in many ways. The pure metal can, however, exist in ordinarily dry air fairly well, although it combines with the oxygen of the air readily when a flame is applied. It is used for giving artificial light for photographic purposes. Magnesium may be obtained by electrolysis of the chloride or by heating it with metallic sodium. It generally is found in nature as the carbonate, and when this is heated it gives off carbon dioxide readily and forms magnesium oxide, or *magnesia,* which is used for toilet purposes, as an insulating material, and in medicine. Magnesium sulphate, or *Epsom salts,* was first found at Epsom, England, in a spring water. It is much used as a cathartic. Magnesium peroxide (MgO_2) is convenient for liberating active oxygen. The powder decomposes slowly in moist air, giving off oxygen.

This little account of chemical substances would not be well balanced without saying a few words about the so-called *halogens,*—fluorine, chlorine, bromine, and iodine,—although they are not important to most people who do not expect to study chemistry systematically. They are not familiar substances in themselves, and compounds of most of them are discussed elsewhere.

HALOGENS.

Element	Atomic weight	Characteristics
Fluorine	19.	Colorless gas, corrosive, poisonous, very active chemically.
Chlorine	35.4	Yellow gas, less corrosive, active chemically but less so than fluorine.
Bromine	80.	Orange-red liquid, irritating but less active than first two; sublimes.
Iodine	127.	Steel-blue solid, yielding a violet vapor.

Bromine is very little used except in combination, being used most as bromides in medicine. Iodine is chiefly used in medicine for local application in alcoholic solution (*tincture of iodine*). It will be noticed how the halogens respond to the principles of the periodic law. As the molecular weight increases they become denser and deeper in color.

Sulphur should not be treated with the alkalies any more than the halogens, but there is so little that need be said about sulphur in this account of things that it can hardly be given much space. Sulphur occurs largely in combinations, such as sulphide of iron (pyrites), sulphide of lead (galena), and sulphide of zinc (blende), but, due to volcanic agencies, etc., it occurs in a few places as the element sulphur. It was obtained almost exclusively from Sicily until it was found in Louisiana, where it is melted in its underground beds with steam and brought to the surface in pipes. This is a great engineering triumph.

Boron is an element which is used at present only in combination, as boric acid or borates, such as borax ($Na_2B_4O_7 . 10\ H_2O$). The ore used in this country is the calcium compound, or Colemanite, found in Death Valley and elsewhere in California. Most of it is brought to the vicinity of New York, where, by the interaction of soda ash, it is converted into the sodium compound, or borax. At Searles Lake, California, and elsewhere it is found in sodium combination with excess of sodium carbonate and potassium salts. These deposits seem to be ripe for development and it is to be hoped especially that an abundance of potassium salts will be produced from such sources. Borax is valuable as a mild alkali, and useful in the household for bathing and cleaning clothes, dishes, etc. It softens water and neutralizes acids.

PLATE VIII.

Courtesy of Union Sulphur Company.

Pumping sulphur into storage bins in Louisiana (Frasch Process).

Courtesy of Richard K. Meade.

Rotary furnace for the continuous burning of cement rock.

CHAPTER IX

METALS

MANY people consider metals as strong, hard, tough substances, but the metals sodium, potassium, etc., treated in the last chapter, are soft and others are brittle. Those described at greatest length here, however, are the toughest and strongest.

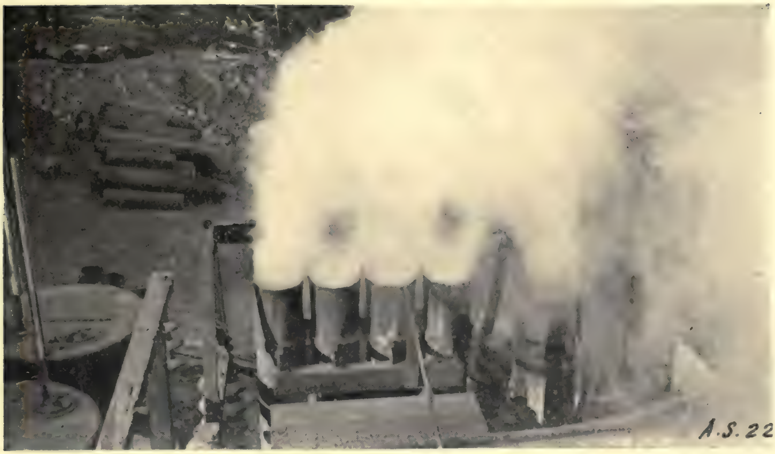
Metals are so varied in physical properties that there cannot be any uniform description except as to the so-called metallic lustre they possess. At ordinary temperature hydrogen is a gas that burns to form water vapor with oxygen, and few would think of it as a metal. Yet it oxidizes like the metals, it unites with chlorine like metals, and when chilled with liquid air it first becomes liquid and then solidifies and looks like silver or lead. Hydrogen, for reasons of convenience, is usually treated in books with the non-metals. We really have metals as gases like hydrogen, liquids like mercury, and solids like iron. Iron and other metals which are solid at ordinary temperatures can be liquefied by heat, and at higher temperatures will volatilize.

The substances found in the earth from which metals are obtained are called *ores*. If they contain sulphur or carbon dioxide in combination, as most of them do, they are first roasted to obtain the *oxides*. Oxides are then converted into their respective metals by smelting or heating to high temperatures with carbon (coke or charcoal), frequently in the presence of lime, to slag with the silica, present as an impurity.

Most metals tend to revert to their oxides, which happening governs the usefulness of most of them. The so-called noble metals—silver, gold, platinum, and a few very rare ones, such as iridium—do not tend to oxidize even on heating to high temperatures with access of air. This means they do not tarnish easily, and it gives them special value.

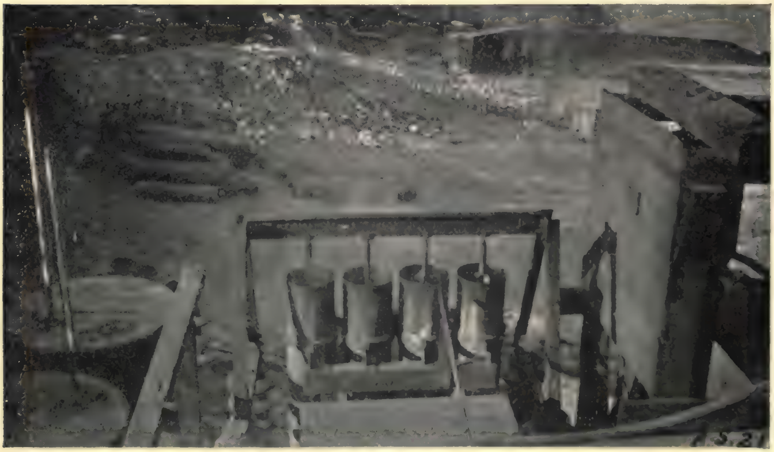
A great many chemical and metallurgical plants send off gases that may in some cases be deleterious to man and certainly are ruinous to vegetation. Acid fumes kill vegetation, and fine dust blights or kills it. With acid gases the effort is now generally made to utilize them in some way rather than to liberate them. Sulphur dioxide gas (sulphurous acid) is now made into sulphuric acid, while some time ago it was wasted from almost all smelters. Recently Professor F. G. Cottrell and associates devised and developed an ingenious process for removing fine dust and otherwise uncondensable vapors issuing from manufacturing plants and smelters. It was found that a very high tension direct current of from 15,000 to 45,000 volts, silently discharging from electrodes in a smoky or va-

PLATE IX.



Courtesy of the Research Corporation.

Fumes from stacks before turning on high voltage current.



After turning on current. Note absence of smoke. Cottrell process for fume precipitation.

porous atmosphere, caused the particles to coalesce and fall by gravity. This process will prove of great value in regions troubled by fine dust and acid vapors from smelters. Much of this dust is rich in arsenic and is not desirable as a substitute for snow. This process also applies to black smoke, from which it will remove the soot if properly applied. Thousands of tons of carbon soot fall in Pittsburg and suburbs every year, and some such process ought to be put into application very promptly in the Pittsburg district and many other places as well.

Iron (Fe) is one of the greatest gifts of nature to man, and with its use man has fought and worked his way onward and harnessed the great forces of nature for his benefit. Iron production shows to advantage the progressive spirit that has given this country such a marvellous growth, and the recent development in other countries has been most marked by improvements in the production of iron, steel, and their manufactured articles.

Iron ore (essentially iron oxide, hematite, Fe_2O_3) in some localities is mined with steam scoop shovels and dumped at once into cars, which in many cases are picked up bodily and their contents dumped into the holds of boats. At the blast-furnace where the iron is made everything is handled by travelling cranes, etc. The charge in the blast-furnace is composed of limestone, iron ore (Fe_2O_3), and coke (C). These are dumped in layers at the top of the blast-furnace through a hopper, and a cover called a *bell* closes over the charge. Air heated by gases from the furnace is used to force the combustion. The air is first freed of moisture by refrigeration, the invention of James Gayley. Chemists and engineers were at first inclined to doubt the efficacy of this additional step in the process, but a short time of use has amply justified Gayley's idea. The power for this refrigeration, the heating, and the blowing comes from the gases of the furnace, which are tapped off and used in gas-engines. The action in this furnace is essentially: Carbon monoxide reduces the iron oxide and lime makes a fusible slag with the silica, present as impurity in the ore.[1] This pig-iron from the blast-furnace always contains dissolved carbon, phosphorus, and silicon, and it is purified, on being made into steel or wrought iron, by blowing air through it while at a white heat, which oxidizes the silicon and phosphorus and burns out the carbon. This is the action of the Bessemer converter. The *open-hearth* furnace does similar work by heating the iron which contains the silicon in the presence of air and lime. The oxygen of the air (or some supplied by means of iron oxide) changes the silicon, phosphorus, and carbon into oxides,

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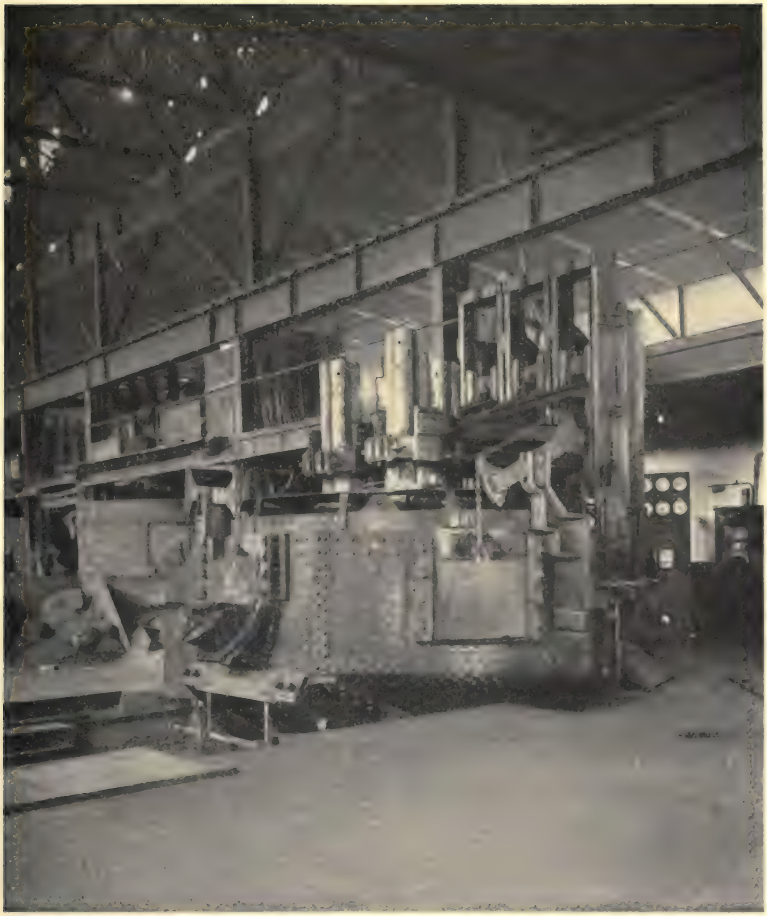
[1] $Fe_2O_3 + 3CO = Fe_2 + 3CO_2$.

PLATE X.



Courtesy of Dr. E. F. Roeber.

Heroult electric steel furnace.

and the lime neutralizes and separates them from the metal.

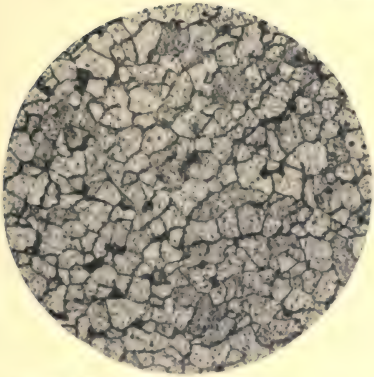
There have been a great many improvements recently in the production of iron and its alloys. Pure malleable iron has recently been made electrolytically. Earlier attempts to make pure iron electrolytically gave a brittle alloy of iron with hydrogen. By alloying iron with an excess of chromium and a little molybdenum an alloy is obtained that resists nearly all acids, even when concentrated. Steels have been made for safes that it is claimed cannot be drilled or exploded even by those adept in the art.

The highest degree of refinement in the making of steel is attained by heating it electrically while lime is thrown into it to remove phosphorus, which cannot be taken out as thoroughly in the converter or open-hearth furnace. This makes steel which is stronger and denser than ordinary steel. Steel contains a little combined carbon, but no admixed or graphitic carbon, as does cast iron. In *tempering* steel it is heated to redness and plunged into water. This makes it very hard, but it must then be heated up to a moderate heat, but not to redness, to toughen it. The latter process is *annealing*. In recent years the microscope and affixed camera have been introduced for examining and recording the appearance of polished sections of metal. Much light has thus been thrown on the wearing away of rails used for transportation purposes.

The accompanying illustrations opposite pages 118 and 120, for which the author is indebted to Professor Albert Sauveur, show the micro-structure of different kinds of iron and steel. It can readily be seen how the character of metal to be subjected to great physical strain can be ascertained before use. When metal, such as a defective rail or steel work of a bridge, gives way, photomicrographs will show the reason if the steel is defective or unsuitable for the purpose. The chief desideratum is to have steel as homogeneous as possible, so that the parts of the metal are continuous throughout, and not have particles of iron sulphide, iron oxide, or carbon, etc., between the steel particles. To minimize corrosion of iron or steel it is also desirable to have the metal uniform throughout, and photomicrographs will show this condition. Cuts 1 to 6 show different kinds of steel; of course they look much more dissimilar under the lenses than to the unaided eye, but the different ways these metals would act in use are quite as various as the pictures. Cuts 7 and 8 show two important kinds of cast iron. Number 8 has less metal between the iron particles, so that it is stronger than the gray iron.

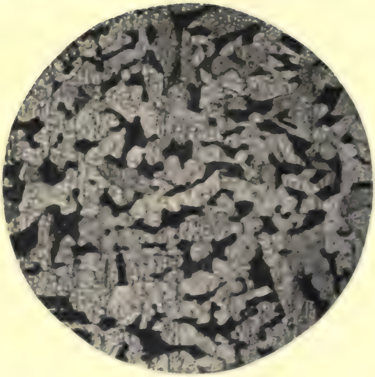
The *corrosion* or rusting of iron and steel is a matter of considerable economic importance, and seems to the

PLATE XI.

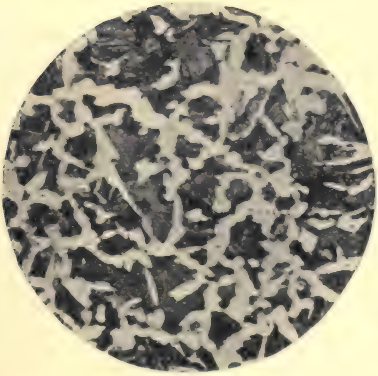


Courtesy of Prof. Albert Sauveur.

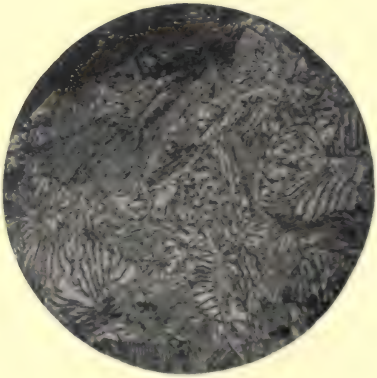
1. Soft steel—0.10 per cent. carbon.
100 Diams.



2. Steel about 0.30 per cent. carbon.
100 Diams.



3. Steel about 0.50 per cent. carbon.
100 Diams.



4. Steel eutectoid, 0.85 per cent. carbon.
400 Diams. (note homogeneity).

writer of sufficient general interest to treat of in this book. Some people have noticed that iron or, more particularly, steel articles corrode more readily than they did a generation ago. If this observation be correct—and it probably is—the difference is due to the substitution of steel (with its impurities) for pure wrought iron. Wrought iron used to be made more readily than steel and for many purposes was better than steel. Now comparatively little wrought iron is made, but steel is supplied in its place. Steel is made first, and the soft steel or iron, when finally made by continuing the process, does not seem to be as good for tinning, fence wire, etc., as the old-fashioned wrought iron.

Pure iron does not rust with water alone or with water and oxygen. It is only when carbon dioxide is present that iron rusts.[2] But as carbon dioxide is always present in the air and in most natural waters, it is not unusual to have conditions suitable for rust formation. It will be seen from the reactions in the footnote that the rusting of pure iron takes place in two stages. Generally one does not note the formation of bicarbonate, as the carbon dioxide gas is not in evidence, but when the carbon dioxide acts with partial exclusion of air the bicarbonate of iron goes into solution, and then, when aërated, the water becomes red with ferric hydroxide (iron dust). Many underground waters contain colorless bicarbonate of iron, which is turned to ferric hydroxide (red) by action of the air.

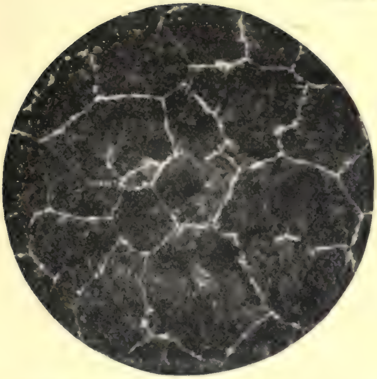
---

[2] (a) Iron + carbon dioxide + water + oxygen = bicarbonate of iron
Fe_2 $4CO_2$ $2H_2O$ O_2 $2FeH_2(CO_3)_2$

(b) Bicarbonate of iron + oxygen + water = iron rust + carbon dioxide
$2FeH_2(CO_3)_2$ O H_2O $2Fe(OH)_3$ $4CO_2$

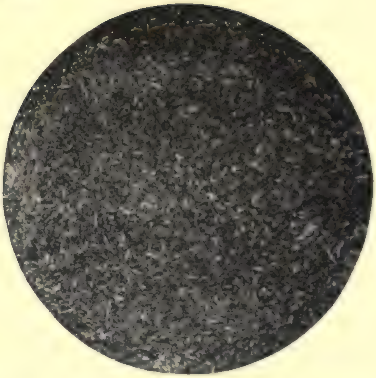
Cast iron and steel are not pure iron and they rust more readily, due to galvanic action set up by the impurities, and carbon dioxide is not requisite, although cast iron has a silicious, rust-resisting coating when new. The impurities in cast iron and steel, such as carbon, sulphur, manganese dioxide, mill scale (in rolled steel), etc., are electronegative to iron, and if water be present oxygen forms on the iron, unites with it, and makes oxide or hydroxide. Hydrogen is evolved from the electronegative particles (generally of microscopic fineness). Dilute acids promote corrosion by making electrically conductive battery fluids to facilitate the chemical action of the iron and the non-iron particles. Acid salts and neutral salts (alum, table salt, etc.) act similarly, but alkaline salts and alkalies (borax, washing soda, etc.) retard or prevent corrosion. The purest iron and the purest steel corrode least readily. In cases of solution of iron, water is necessary as well as acid, and anhydrous acids do not dissolve metals at all. For instance, concentrated sulphuric acid may be stored in steel tanks and transported in steel tank cars. A very little copper is sometimes added to steel, which

PLATE XII.

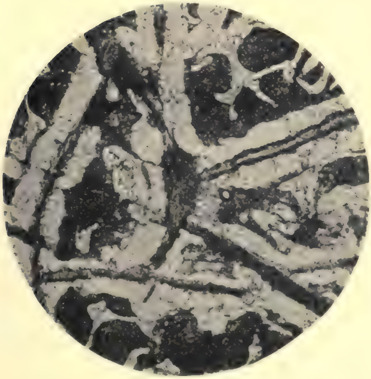


Courtesy of Prof. Albert Sauveur.

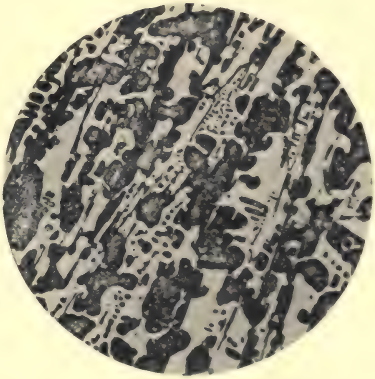
5. Steel hypereutectoid, 1.10 per cent. carbon. 100 Diams



6. High carbon, hardened steel. 100 Diams.



7. Gray cast iron, No. 2 foundry. 100 Diams.



8. White cast iron. 100 Diams.

is supposed to make it more resistant to corrosion, but the best solution probably lies in absolute purity.

While alkalies protect iron from corrosion, they cannot be employed often for that purpose, except that the cement coating much used on steel girders, etc., is, in a way, alkaline in reaction. Zinc coatings protect iron from corrosion, as explained on page 125. Nickel, copper, and tin protect iron only when they completely cover it. As they are electronegative to iron, like the particles of sulphur, carbon, etc., in steel, and broken surfaces in the presence of moisture facilitate corrosion of the iron.

Another phase of this subject is the electrolytic corrosion of underground pipes due to stray electricity from street railways using them as conductors, because of the less resistance of iron than damp earth. Where the current enters the iron (cathode) hydrogen is evolved, which does not act chemically on the iron, and alkali is formed, which protects it; but where the current leaves the iron (anode) oxygen is evolved, which causes corrosion, due to the influence of oxygen and free acid that is formed. With lead cables the opposite seems to happen. The cathode pole corrodes, due to the alternate alloying of hydrogen with lead, and the chemical action of oxygen in the soil which causes the formation of lead oxide. Remedies for these troubles have been found by engineers. Pipes are bonded to the rails of the electric lines in some cases, and in others zinc is fastened to the pipes or other underground iron work. This acts like the galvanizing directly on the metal by giving up itself to electrolytic corrosion instead of the iron or steel.

Aluminum (Al) has been referred to as being present in the soil in predominant quantity as clay. Aluminum, as metal, cannot, however, be readily extracted from clay, and it was not made economically until a way was found to make it from alumina, produced from the mineral bauxite, a hydroxide of aluminum and iron.

The writer remembers, when a boy, seeing aluminum when it cost $20 per pound, whereas it is now sold for about 18 cents per pound. The great step forward was made by Charles M. Hall when just out of college. He dissolves alumina (the oxide of aluminum) in molten cryolite, which latter is a double fluoride of sodium and aluminum, and then electrolyzes[3] the mass, depositing aluminum as molten metal on the negative pole, which consists of iron, while carbon serves as the positive pole. Alumina is piled above each furnace and dissolves in the molten cryolite as fast as required.

Aluminum is the lightest metal that is reasonably stable in the air. One of the greatest uses for the metal now is for stamping out all kinds of utensils for the kitchen and home and small articles generally. These vessels are very little attacked by vegetable acids, etc., in use, and any white tarnish that forms is harmless. Aluminum tarnishes or becomes corroded by overheating, and rubbing with a silica powder or silica soap is generally necessary to polish it. Aluminum is more resistant to acids than it is to alkalies. It has been introduced for lining tanks for the transportation of nitric acid in bulk. Aluminum should not be used for alkaline solutions; even ordinary alkali carbonates attack it. Aluminum is much used as wire for carrying heavy electrical currents, as it will carry more current than copper for equal weights. Its use is governed generally by the price of copper, which fluctuates considerably. Its lightness renders it valuable for automobile, motorboat, and aëroplane construction. Finely powdered aluminum is used as paint pigment for radiators, pipes, and painting metal surfaces. It is also used in flash powder, as it is easily burned by oxidizing agents that are intermixed intimately and gives a brilliant light. A somewhat similar reaction happens in the Thermit process, in which an oxide, such as iron oxide, is mixed with powdered aluminum. The aluminum has more affinity for the oxygen than the iron, and when the mixture is touched off by a fuse there is a large amount of heat liberated, a brilliant light is created, and molten iron or steel is formed, which is run into moulds to repair breaks in iron or steel castings, etc. This same process has been used successfully for producing many metals in the pure state, such as tungsten.

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[3] $2Al_2O_3$ (+ electricity) $= 2Al_2 + 3O_2$.

Aluminum salts are used as mordants and for many other purposes. The chief salt is aluminum sulphate or concentrated alum ($Al_2(SO_4)_3 + 15H_2O$), and differs from common alum in not having any alkaline sulphate crystallized with the aluminum sulphate; consequently, it is more concentrated in active principle, as the alkaline salt is inert. Fused alumina (Al_2O_3) is used as an abrasive and to make crucibles, etc., for the laboratory.

Zinc (Zn) has been used as a metal for several hundred years, and from very ancient times alloyed with copper as brass. It seems rather strange that it should be known in the alloy form before it was known as pure metal, and it would seem as if copper was thought necessary in the reduction of the metal. The chief ores of zinc found in the United States are zinc sulphide, zinc silicate, and a composite mineral, called franklinite, composed of zinc, iron, and manganese oxides. As the sulphide, or "zinc blende," is the predominant ore, we will briefly refer to its use. The ore is freed mechanically as well as possible from silicious matters called gangue, and then roasted at a high temperature in the presence of air to form the oxide. This oxide of zinc is distilled[4] in relatively small clay retorts with coke and the zinc vapor condensed. A commercial plant has rows of such retorts with the cooler ends and condenser sticking out of the furnace walls. Bluish-white flames flicker at each retort where incandescent zinc vapor is burning as it leaks out. It is now proposed to reduce and distil zinc in large furnaces by means of electrically produced heat.

Zinc is used in alloys, to most of which, like brass, it gives hardness. Like copper, it is employed in sheet metal for exposed places, as it does not corrode seriously with water. It is used, however, mostly as coatings on steel sheets or cast-iron objects (called galvanized iron), which it protects for some time if the underlying metal is covered. Even when only partly covered, it protects for quite a while by galvanic or electrolytic action from the rust-producing effect of moist air. This is because zinc tends to corrode rather than iron, and slowly wears away, leaving the iron free from rust, until very little zinc is present. Copper in contact with iron, galvanized iron, or zinc causes corrosion of these metals. Brass, which is an alloy of metals with opposite electrical properties, happens to be nearly electrically neutral to iron. Brass rich in copper, or red brass, acts somewhat as a galvanic couple with iron, because of the predominance of copper.

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[4] $2ZnO + C = Zn_2 + CO_2$.

Zinc oxide (ZnO) is probably the most valuable product of zinc other than the metal, and is used as a pigment in paints with or without white lead. It covers better than white lead, and it does not seem to have as much tendency to *chalk off* as white lead, and is not discolored by hydrogen sulphide. The best article, the writer believes, has both present. Zinc chloride is a soluble salt of zinc which is used for impregnating wood to prevent decay. Zinc sulphate is used for making many chemical substances and in the arts.

Copper (Cu) occurs in nature chiefly as native copper, the sulphide, and the carbonate. Near the surface of the ground in copper-mining districts, carbonate of this metal is found, but the most of the ore mined is sulphide, which is found in strata below the carbonate. The smelting of copper is very complicated and it would take a good deal of space to treat the matter fully. It is, essentially, a heating[5] of copper oxide and sulphide in closed furnaces. Most copper is not a finished, manufactured article now until the smelted product is refined electrolytically. In this operation copper is dissolved at the anode, or positive pole, and is precipitated quite pure at the cathode, or negative pole, of an electrolytic cell. Silver and any gold in the crude articles are caught as a sludge and refined separately.

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[5] $2CuS + O_2 = Cu_2S + SO_2.$
$2CuO + Cu_2S = 4Cu + SO_2.$

Copper is valuable for its ductility, malleability, toughness, and non-corrosive character. It tarnishes, but this skin of altered metal protects the body of the metal. It is alloyed with gold and silver in coins, and with other metals in bronzes.[6] Copper is used for electric machines and wires on account of its conductivity and for roofing, etc., as it does not corrode. Copper is not affected by weak acids, such as are in foods, so it can be used for cooking vessels. These must be kept dry and polished, as a little water on contact with air will cause the formation of a green film of basic copper carbonate. Ammonia dissolves copper in the presence of air, forming a blue solution which will dissolve cellulose. Copper plating on iron by means of electricity is sometimes practised, and a cyanide bath must be used. If clean iron is merely dipped into copper sulphate it is covered with a coating of copper, but it is so thin that it is no protection to the iron, and, in fact, it is apt to make the iron rust by galvanic action.

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[6] Alloy	Copper	Tin	Zinc
Brass	66	..	34
Bronze	84	10	6
Gun-metal	90	..	10
U. S. Cent	95	2	3

The chief copper salt is the sulphate called "blue vitriol," and is used to make insecticides such as Paris green, copper arsenate, and Bordeaux mixture, which is copper hydroxide precipitated from the sulphate by means of milk of lime.

Lead (Pb) is generally found as the sulphide, called galena, and is smelted much like copper by first roasting and then heating in the absence of both air and carbon. Most metal ores are roasted to oxide and then reduced with carbon to the metallic state, but lead and copper are roasted just enough to make a partial oxidation and then this oxide acts on the unchanged sulphide. Lead is soft, tough, melts at a low temperature, and is not attacked readily by acids or other chemicals. These properties give it wide usefulness for piping connections and lining tanks, making plates for storage batteries, etc.

Lead is corroded by the joint action of acetic-acid vapors and carbon-dioxide gas to form white lead, or basic carbonate ($2PbCO_3 . Pb(OH_2)$). Lead also forms the yellow color, lead chromate.

Mercury (quicksilver, Hg) is the only metal that is liquid at the ordinary temperature. It is found as the sulphide, or cinnabar (HgS), in Spain, California, Texas, and elsewhere. Merely heating this ore causes mercury to separate from sulphur. Both distil, the mercury is condensed, while the sulphur combines with oxygen to form sulphur dioxide gas. Mercury is not produced in as great quantities as most other metals, as the uses for it are more limited and where it is used it is not consumed very fast; for instance, in making thermometers, in electrolytic production of sodium hydroxide, and in the recovery of gold from admixture with silica and clay. Mercury is over thirteen times as heavy as water. A small jar holding a pint would weigh about 13.9 pounds.

If some mercury is put into a dilute silver nitrate solution, an interesting action ensues. The mercury has a greater affinity for the nitric acid radicle than the silver, so it goes into solution, and the silver is precipitated and at once unites with the excess of mercury to form an alloy, which crystallizes quite beautifully in arborescent shapes, known to the alchemists as "Arbor Dianæ." (See page 19.)

Tin (Sn) is a metal that is useful in its protective influence on other metals. This protective influence is rather over-estimated, however, in many cases. A uniform and fairly thick coating would protect steel sheets, for instance, but what is put on is often not a uniform coating. There generally exist minute pores in tin plate, due to impurities in the sheets, which the tin does not fully coat. Roofing tin plate is generally composed of a tin-lead alloy, called *terne plate,* and usually contains a distinctly minor percentage of tin. Solder is also a tin-lead alloy. Pure tin piping is much used for water-pipes in high-grade water-filters, in condensing worms, etc. Tin-foil is often tin-lead, but for coating foods, such as cheese, chocolate, etc., it should be made of pure tin, because of the poisonous action of the lead.

Nickel (Ni) somewhat resembles iron, although it is not so easily corroded. Most of the nickel we use is from Canadian ores. Nickel is smelted somewhat like copper, but is refined by an ingenious process devised by Ludwig Mond, an English chemist. Carbon monoxide (producer gas) is blown through the moderately hot metal, and this volatilizes the nickel and removes it from the impurities. When at a slightly higher temperature the gas is made to give up the nickel. Some nickel is smelted directly with copper that was associated with it in the ore, and this makes *Monel metal.* Monel metal takes valuable properties from both the nickel and the copper. It is tougher than nickel and stronger than copper. It is not easily corroded and is used for fly-screens, which are very satisfactory. *Nickel coin* in this country contains copper, 50 per cent., and nickel, 25 per cent. Monel metal consists of copper 40 and nickel 60 per cent.

Manganese (Mn) is a metal that has been known for a good while and has been used in steel to strengthen it. Of the salts, potassium permanganate is the best known and is used as an oxidizing agent. A dilute solution of this is sometimes used as an antiseptic.

Manganese dioxide (MnO_2) is a valuable oxidizing agent used as drier for oils and in dry-cell electric batteries to absorb nascent hydrogen around the carbons. This action is called *depolarization* and the manganese dioxide is therefore called a depolarizer.

Chromium (Cr) is obtained as an oxide usually associated with iron as chrome iron ore. The metal is used to make chrome steel, but is chiefly used to form salts or chromates such as have been referred to under sodium salts and under lead.

Tungsten (W) is found in reasonable quantities in the Western States, chiefly as the mineral wolframite, or iron tungstate ($FeWO_4$). The metal itself has only recently been made pure enough to draw out in the wire for electric lamps. This wire is drawn through diamond dies as small as 1/40 millimetre. Tungsten is used for these filaments because of its high melting point. Tungsten is also much used in small percentages to harden steel.

Vanadium (V) is used like tungsten to make a special steel which is very tough and strong.

Thorium (Th) is a rare element obtained from monazite sand, found principally in the mouths of rivers on the coast of North Carolina. There are other rare elements also present in this sand. Thorium is converted into nitrate ($Th(NO_3)_4$) and then into oxide when the incandescent gas-mantle filaments are made. The mantles, when the cementing pyroxylin lacquer is burned off, consist of about 98 per cent. thorium oxide to 2 per cent. cerium oxide.

Cerium (Ce) is another so-called rare earth metal, the oxide of which is produced from monazite sand to be used with thorium oxide for incandescent mantles. The metal itself is also produced and is alloyed with iron to make a *sparking gas lighter* used in place of matches by rubbing on a short steel file.

Arsenic, antimony, and *bismuth* are metals that are well known to chemists, but not of great interest outside of using certain of their compounds employed in medicine and the arts.

Arsenic (As) is used in insecticides such as Paris green. *Antimony* (Sb) occurs as metal in alloys with lead, which it hardens. Its chief salt is tartar emetic, or antimony potassium tartrate. It is used as a mordant in dyeing. Bismuth is used in medicine as *subnitrate of bismuth,* a sedative. As a metal it is used to cause lead alloys to melt at very low temperatures, even below the boiling point of water. This alloy is then used for automatic fire sprinklers, which are actuated by the presence of the water after the fusible alloy has melted.

CHAPTER X

GOLD AND SILVER

THE so-called noble metals are silver, gold, and platinum. The chief chemical property in which these metals differ is their solubility in acids. Silver is soluble in several acids, particularly nitric. Gold and platinum are not dissolved by any one acid, and it is only by the combined action of nitric and hydrochloric acids (called aqua regia) that they can be dissolved. *Platinum* (Pt) is used to make crucibles and dishes for the laboratory, as it withstands nearly all reagents, and temperatures up to 1760° C. (3200° F.). It is 21.5 times as heavy as water. It is very costly, about $50.00 per ounce being paid for it in 1914. This is due to the limited supply and its recent use in jewelry and in electric light bulbs, as well as in the laboratory. For making jewelry and other objects out of platinum, iridium up to 10 per cent. is alloyed with the platinum to make it stronger.

Silver (Ag) has been a highly prized metal since the earliest antiquity. It has been just rare enough to render it somewhat costly, yet can be used for many purposes. It is, like gold, largely used for ornamental purposes, and its comparative scarcity and its being only slightly subject to corrosion renders it a desirable medium of exchange and sometimes a standard of value. Silver is produced from sulphide ores by roasting and smelting, generally in the presence of lead, because it is found, as a rule, with lead, and lead protects it against loss. It is precipitated from melted lead by a little zinc, as silver is more soluble in molten zinc than in lead. Zinc can then be distilled off at temperatures which leave silver behind. Silver is malleable and ductile but harder and less easily tarnished than lead. Hydrogen sulphide gas, however, readily darkens silver. Even the sulphur compounds in eggs will darken silver by forming silver sulphide (Ag_2S) if left in contact with the metal very long. This is nearly the only drawback to silver, although some people object to handling silver dollars. Most people could carry their week's wage in silver, however, as a dollar weighs about an ounce avoirdupois.

	Silver (fine)	Copper
U. S. coin	900 parts per M.	100 parts per M.
Table silver	750–950 parts per M.	250–50 parts per M.
Sterling	925 parts per M.	75 parts per M.

Sheffield plate is not, as some people think, electroplated on base metal, but is (or should be, to be genuine) composed of sheets of silver and copper that have been rolled together at a temperature a little below the melting point of silver. Silver plating is an art that has been greatly improved of late by the introduction of mechanical appliances that rotate the articles so that they are coated uniformly. There are polishes on the market that really do plate silver on places where brass or base metal is exposed, as well as clean. This is effected by having a little silver in the preparation in a state of chemical instability, and the base metal of the article, such as copper or zinc (in brass), tends to go into solution in place of silver, as it can form stronger compounds.

To clean silver where no coating is necessary, the best way is to do it electrolytically. There is now on the market an arrangement which consists essentially of a zinc tray with racks to hold the silver. A bath is made up of a hot solution of salt and bicarbonate of soda. When the more or less tarnished silver is immersed in the liquid and in contact with zinc, galvanic action is set up. The zinc is electropositive to silver, forming an anode, which goes into solution as chloride. The sodium which was combined with the chlorine to form salt goes to the cathode or the silver. It acts upon water at this place, releases hydrogen, and forms sodium hydroxide. The hydrogen, in process of formation, acts upon silver sulphide (the tarnish) and reforms silver, while the sulphur goes into the solution. Of course, the caustic soda formed takes some carbon dioxide from a little of the bicarbonate, forming normal carbonate. These pans offer a nice little lesson in electrochemistry and improve the appearance of the silver without much labor.

Silver can be coated on practically any article, even glass. A coating of silver called a "silver mirror" can be produced on glass by the use of unstable silver solutions.[1]

As silver salts are the chief active agents in making photographic images, we must say something about the essentials of the chemistry of photography. The dry plate (in contradistinction to the earlier wet plate, which could be used only by professional photographers) is coated with a gelatin emulsion containing a silver halide, such as silver bromide (AgBr), in a finely divided, freshly precipitated condition. In the case of films, thin strips of transparent celluloid are coated with gelatin. The high lights of the object reduce the silver bromide more or less completely to a compound containing less bromine (Ag_2Br). The negatives still look milky white, due to silver salt, after exposure in the camera.

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[1] *Silvering on Glass.*—When alkaline solutions of silver salts are mixed with certain organic compounds like grape-sugar, Rochelle salt, etc., the silver is deposited on the surface of the vessel in which it is contained as a thin, coherent film. The following process will yield satisfactory results if the glass be first thoroughly cleaned with alkali and then washed with distilled water:

Dissolve 7.8 grammes of silver nitrate in 60 c.c. of water and divide the solution in two equal portions. Dissolve also 3.11 grammes of Rochelle salt in 1180 c.c. of water and heat the solution to the boiling point. Add to it gradually (so as not to stop the ebullition) one of the portions of silver solution, boil some 10 minutes longer, cool, and decant the clear liquid. To the other half of the silver solution add just sufficient ammonia water to dissolve the precipitate which is first formed, or only leave a faint cloudiness; then add 360 c.c. of water and filter. Equal portions of these two solutions, when mixed and poured on glass, will deposit a brilliant coating of silver in about 10 minutes, according to the temperature of the room. The coating of silver should then be well washed, dried, and varnished. (Sadtler and Coblentz.)

The plates are next put in the developing bath, which is composed of an organic substance that is capable of changing this acted-upon bromide to metallic silver which is black and opaque. These developers are known by names as hydroquinon, ikonogen, metol, etc., and owe their efficiency to their being mild reducing agents. The next operation is to put the negatives into a solution of sodium thiosulphate, commonly called "hyposulphite of soda," which dissolves out all the unchanged silver bromide. The lights of the image are now represented by dark places in the negative and shadows by transparent areas. After thorough washing and drying, the negative is completed and the positive is now to be made. For this purpose paper that is coated with a similar solution to that on the plate, only less sensitive to light, is exposed to the light that comes through the lighter areas which correspond to dark parts in the image. This makes dark places on the positive. The processes employed in treating the positive are a little different from those of the negative. The first solution is a "toning" solution which contains gold or platinum salts. The silver bromide which has been affected by the light is capable of reducing gold or platinum salts, the metals of which take the place of the altered silver bromide. Then by the use of "hypo" again the paper is cleared of unaltered silver salt. In making this positive, the lights and shadows are reversed again, which therefore makes the image the true one, as it was reversed in the negative, both in light and shadow and in the location of objects.

There have been great advances in the chemistry of photography in negative developers and in printing papers. It was difficult for a long time to get the true color value of red lights, which showed up quite dark with ordinary processes. Now it is possible to get the true value by having red colors in the gelatin emulsion or silver compounds of red colors, such as the organic color eosin. This process is called orthochromatic photography. Thus red rays are somewhat absorbed, which makes the total light shown about normal. Color photography is still in its experimental stages. It is possible with color screens to make three negatives so that each takes certain colors, and a composite lithographic print or lantern-slide can be made that shows in their true values the colors of the original. It is not yet possible to print directly on paper in colors from an exposed plate.

Gold (Au) occurs native or "free" in quartz or gravel. It occurs combined in lead, copper ores, and as telluride of gold, etc. Gold is obtained from quartz by crushing in stamp-mills and collecting the particles by means of mercury, which has a strong affinity for free gold, and the mercury is easily separated from the wet, crushed ore because of its weight and fluid condition. In so-called "placer" mining streams of water from high-pressure pipe lines rip out the sand and earth, tearing down whole hills. The gold is so much heavier than the gravel that it does not go so far in the water-course that results, and is caught in sluices as practically pure gold or "gold dust." Besides these ways of obtaining the gold, the cyanide method is the most important, and after that the chlorine method or chloridizing. These are chemical methods and the preceding are physical, as solution in mercury does not effect a chemical change in the gold any more than salt is changed when it dissolves in water. Gold is thrown out of solution from cyanide of potassium or chlorine water by means of zinc strips or by electricity.

Gold coins are 90 per cent. gold and 10 per cent. copper, as pure gold is too soft for practical use and copper hardens it. This alloy would be, by the well-known jewellers' scale, 21.6 carats. Similarly, 18-carat would be 75 per cent. gold, and 14-carat gold is only 58 per cent. pure. Gold is one of the heaviest metals, being about 19.5 times as heavy as water, mercury being 13.5. It is one of the toughest and most malleable of metals.

It can be beaten out into sheets of almost imperceptible thinness. These sheets of gold leaf can be made so thin that they will transmit green rays of light. A form of colloidal gold[2] with tin is made by precipitating gold chloride solution with a solution of stannous chloride ($SnCl_2$). Other colloidal gold solutions are made by the use of ferrous sulphate ($FeSO_4$) and oxalic acid. A red colloidal solution is obtained by adding a little silicate of soda and formaldehyde to gold chloride. This color, *purple of Cassius,* is used to paint porcelain to produce gold bands and decoration.

The story of *radium* is a very weird one and it could easily lead us into chemical theory too involved for this book. It may be told in outline, however, as it has great bearing on chemistry, physics, and cosmogony.

In 1896 Becquerel, a French chemist, discovered radiations emanating from a mineral called pitch-blende, which influenced the photographic plate and made phosphorescent substances luminous in the dark. These were then merely called Becquerel rays. In 1898, however, Madame Curie and her husband, Professor Curie, discovered what afterwards was called radium in pitch-blende residues. One ton of pitch-blende yielded ten milligrammes of radium. The pure radium bromide was

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[2] Fine suspension in water that does not settle out and particles too small to be seen, even with a microscope.

PLATE XIII.

Photo by the Author.

Tray for electrolytic silver cleaning. Alternate pieces of silver have been cleaned.

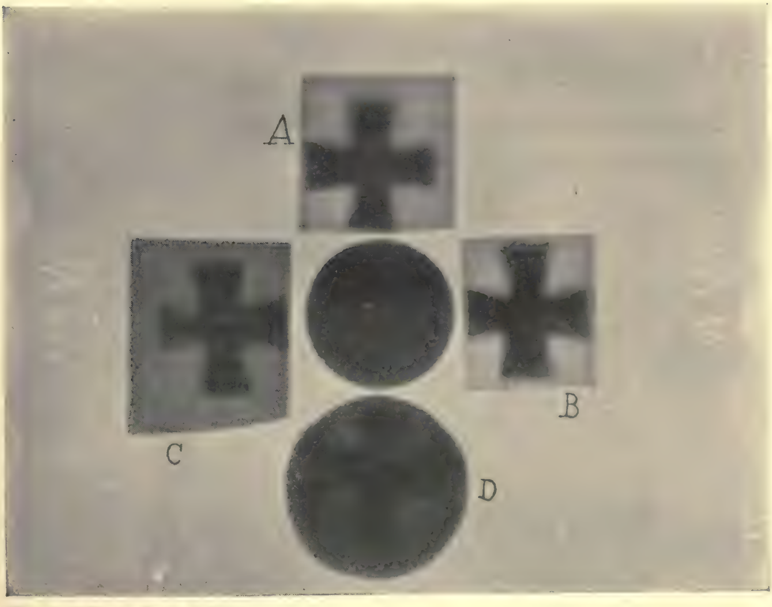

Photo by Williams, Brown & Earle.

Photograph made with radium, showing degrees of opacity of different thicknesses of lead glass. Crosses are lead.

prepared, and radium was found to have a high molecular weight of 226.4, one of the highest molecular weights that is known.

Radium continuously emits enormous quantities of heat because of a molecular degradation that is in progress and the bombardment of matter with the rapidly vibrating negative electricity emitted. It is estimated that all the radium existing will have gone over into other substances, such as helium and what scientists call negative electricity, in about ten thousand years.

Radium is always found associated with the metals of higher molecular weight, such as *uranium*, and there is good reason to believe it has been produced from uranium by dissociation of the latter, just as radium itself dissociates, only it is supposed that the radium now in existence has taken about ten million years to form. In the descent of radium it goes through several stages, giving off helium gas and α rays with very great differences in the rate of decomposition. Radium has very marked activity, which is particularly characteristic of the substance. It makes air a good conductor of electricity, due to the emanation of conductive gas. Thus it draws the electric charge from a gold-leaf electroscope. Radium induces phosphorescence and chemical change. Sir William Ramsay has stated that he has obtained lithium from copper by the influence of radium emanation, but Madame Curie and others have questioned this finding. The subject is a difficult one, and all honor should be given to the opinion of so conscientious and versatile a scientist as Ramsay, particularly as a stable, low-atomic-weight element like copper (63.5) could hardly be expected to dissociate as easily as the high-atomic-weight elements, such as *uranium* (238.5), *thorium* (232.4), and *radium* (226.4), and very little decomposition product might be expected at best.

Thorium goes through a series of degradations much like radium. The products of these transformations, for lack of better terms, are given Greek letters, such as α, β, and γ rays. One of the greatest shocks radium has given science is the thought that the law of the conservation of energy may be violated. This is not in the least true, although the radio-active elements have shown us that the energy of atomic integrity far surpasses any force of union or cohesion of which we have knowledge.

CHAPTER XI

THE CHEMISTRY OF THE EARTH'S EVOLUTION

To CONSIDER properly from a chemical stand-point the changes which the matter of our globe has undergone, we will have to give some thought to the earliest condition of things of which we have any evidence. Laplace, at the beginning of the last century, by studying the movements of planets noticed how they seemed to move in planes relative to each other. This motion, taken in conjunction with the phenomenon of the rings of Saturn and the movement of asteroids, led him to the belief that the solar system had been at one time a rotating mass of hot gases. This gaseous matter in time condensed to a liquid state and finally separated into spherical globules, with the sun in the centre of rotation and the other globules revolving about in the same plane as the original nebula. This hypothesis is generally credited among scientists.

To look at this subject in the most elementary way, we must consider practically the elements we know (with possibly some we have not yet discovered) in a liquid or gaseous condition, forming a revolving sphere. Naturally these elements, more or less in fused solution, together formed the earth at this stage, while the uncondensed gases formed an envelope surrounding the central mass. When the globe was very hot at the surface, say 1000° C. (1832° F.), many elements normally solid would have been in the atmosphere around the earth, just as there are a large number of elements, such as iron, zinc, aluminum, etc., in the sun's atmosphere. The molten mass which by evolution has formed our planet contained the rock-forming elements,—the silica, aluminum, iron, calcium, magnesium, sodium, potassium, etc., while the envelope probably contained oxygen, nitrogen, carbon dioxide, steam, zinc, etc. The earth was different in composition from what it now is, and the primitive atmosphere was certainly very different then from what it is at present, or any time since life has been on the earth. There are reasons for believing that it was at one time too rich in carbon dioxide to support life, and until the earth was cool enough there was no condensed water on the surface, although steam may have permeated the molten rock to some extent, as gases are absorbed by molten metal under certain conditions.

Geologists have made a careful study of the surface rocks, and find that the original rocks which come to the surface in many places are of generally the same approximate composition. How far down from the surface this general uniformity exists cannot be stated. Some think the heaviest metals are at the centre, as

PLATE XIV.

Courtesy of the Lowell Observatory.

Planet Saturn with rings of vapor.

the specific gravity of the entire earth is greater than the surface rocks, and that probably iron constitutes most of the mass at the centre. This idea has been entertained partly because meteorites generally consist of iron or iron and nickel. Others believe that the composition is essentially the same as at the surface and that the increase in density is due to pressure. It would seem probable to the writer that, as the earth was first formed by the most readily condensable elements, such as aluminum, silicon, calcium, and iron, they formed a homogeneous mass which, from the movements due to rotation, would be more or less mixed and made uniform in composition. Oxygen,[1] as the temperature was lowered, reacted with the elements at the surface, and their interaction formed a crust composed of molten silicates, etc., which now compose the rocks.

Judging from the movements of the earth's surface and volcanic activities, it is thought that the solid crust is not very thick, say, about 10 miles. Below this there is molten rock and possibly below this the same elements in a melted state without oxygen,[2] *i.e.*, in a free state. The igneous rocks are essentially like the very hard, durable and widely distributed rock known as granite. The average composition, according to Clark,[3] of this mass is about as follows:

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[1] $2O_2 + Si_2 = 2SiO_2$
oxygen silicon silica
$3O_2 + 2Al_2 = 2Al_2O_3$
oxygen aluminum alumina
$Al_2O_3 + 2SiO_2 = Al_2Si_2O_7$
alumina silica aluminum silicate, or anhydrous clay

[2] This last hypothesis is purely a surmise of the writer.

Feldspar (silicates of alkalies, alkali earths, and alumina)	59.5 per cent.
Hornblendes (magnesia, lime, iron silicate)	16.8 per cent.
Quartz (silica)	12.0 per cent.
Biotite (mica), magnesia, alumina and potassium silicate	3.8 per cent.
Titanium minerals	1.5 per cent.
Apatite (lime phosphate)	.6 per cent.
Less abundant minerals, including the useful metals, such as zinc, lead, etc	5.8 per cent.
	100.0 per cent.

This somewhat complex rock contains all there was on the surface at a time before life began on the earth. From this substance have developed, by a process of evolution, with the help of the atmosphere and the heat of the sun, the varied inorganic materials that make up the surface of the earth. With life in addition all the organic substances were made.

In the main there have been two classes of combined chemical and physical actions on the earth:

A. Tearing-down processes.
B. Building-up processes.

The tearing-down processes began when water started its cycle of precipitation, flowing off the land into the sea, evaporation and passage back to the land, and the work has been kept up incessantly. The building-up processes began when the disrupted substances began to be accumulated in new locations on the floor of the ocean. As the tearing-down processes are going on now, we can form some idea as to what has been in progress through the ages. The only probable difference is that the rate of change has varied. Some of the *tearing-down agencies* that acted upon the original granite or igneous rock, upon rocks formed from it, and upon rocks formed from these rocks may be referred to: (*a*) Rain and flowing water; (*b*) wave motions at the sea-shores; (*c*) glacial streams; (*d*) expansion due to freezing in crevasses; (*e*) wind-blown sand; (*f*) vegetation; (*g*)changes in temperature; (*h*) animals; (*i*) acids, such as nitric, formed from lightning discharges, and carbon dioxide.

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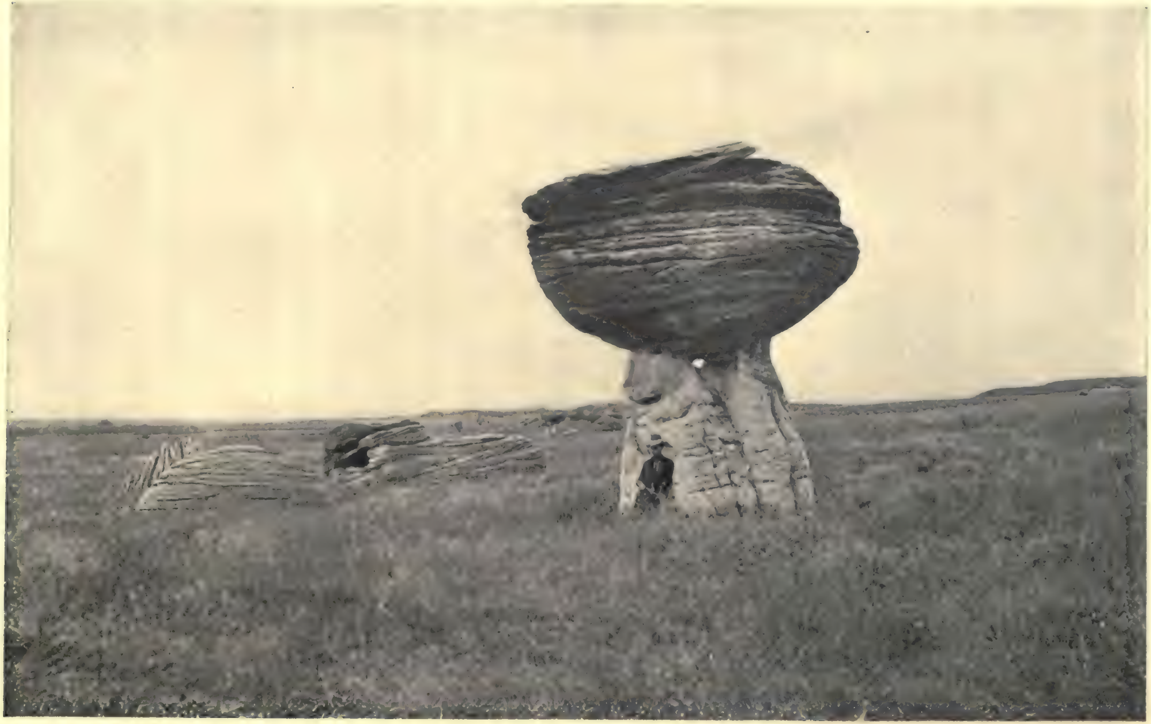
[3] The Data of Geological Chemistry, F. W. Clark, U. S. Geol. Survey, 1908.

Most of these agencies are purely mechanical and their actions are obvious, and only those changes of a more or less chemical nature will be discussed here. Mechanical attacks often precede the chemical, however, and prepare the way for the latter, particularly with the granite, which does not wear away very fast until pieces split off and come in contact with the soil. The rain is a mechanical process, but carbon dioxide, oxygen, and oxides of nitrogen are always ready for joint chemical action. The acids attack the complex silicates, and water frequently combines to form new hydrated minerals. These hydrated minerals are apt to be more bulky than the original minerals and help to disrupt the rocks as driven wedges would a tree trunk. Vegetation has been an important factor in rock decomposition after the start was made. Lichens collect soil on the rocks and vegetation springs up and the roots widen clefts in the rocks. Acids are formed on the decay of the plants as the seasons change.

In arid regions the rocks do not decompose very quickly, but *loess* and *adobe* are formed mechanically by wind-borne particles. In the Hawaiian Islands it is quite noticeable that the rocks on the mountains are quite eroded and worn on the side towards the prevailing moist winds and are angular on the sides away from the rains. In desert places in Southwestern United States the rocks are worn away by sand blasts and by the unequal expansion and contraction due to the great changes in temperature between day and night. These desert sands appear to be barren when dry, but as soon as this soil, composed of mechanically disintegrated rocks, becomes moist from irrigation, it is enormously productive. The reason is the mineral plant foods, such as phosphates and potassium carbonate, are not washed away in rivulets and streams. This soil is alkaline, and it is hard to see why nearly all soil is not alkaline because of the alkalies released from the feldspar. One acid strong enough to neutralize these alkalies is sulphuric acid, formed from the weathering of

PLATE XV.



Kansas Pacific Railroad.

Relics of rock strata showing effect of erosion.

sulphide of iron (iron pyrites). By its action on calcium compounds there is formed calcium sulphate (the chief constituent of most so-called permanently hard waters), and with weak sodium compounds it forms sodium sulphate.

It is a matter of great scientific interest as to whence the sodium chloride (salt) of the ocean was derived, as the mineral matter of the streams differs greatly from that of the ocean. The chief compounds of sodium (in the order of magnitude) are, in the *ocean,* chlorides, sulphates, and carbonates, while in *average river water* the order is carbonates, sulphates, and chlorides. Furthermore, sodium salts predominate very greatly in the ocean, while potassium salts are well up to sodium in quantity in river waters. Why are the lime and magnesia salts greater in river waters than the sodium and less in the ocean? Some explanation of these enigmas may be forthcoming, but we cannot adequately explain all the points of apparent discrepancy that may be brought forth. When elements first began to unite with those for which they had the strongest affinities, sodium (one of the strongest base-forming elements) united largely with chlorine (one of the strongest, if not the strongest, acid-forming element), and in all the changes that have subsequently taken place, where land has risen from the sea or continents have been in whole or in part submerged, the chlorine and sodium have remained combined. Now many of the other elements are carried into the ocean in great quantities in the aggregate, but are weeded out, as it were, by animal life. Silica has been removed by diatoms; lime by coral, shell-fish, crustaceans, etc.; potassium by kelp and other marine plants and the dead plants buried in loam or ooze in the sea floor. Even sulphates are supposed to be changed by some minute organisms, with absorption of sulphur. One reason why geologists have been concerned with the salt of the sea is because they thought they could calculate from its quantity the age of the world, by measuring the sodium that was at present entering from rivers and assuming that the total amount came there by the slow process of supply from these sources.

We have spoken of the tearing-down processes of the elements. These may have been much more rapid at one time when the heat was greater and there was more carbon dioxide in the air. Possibly nitric acid from frequent thunder-storms, due to the masses of clouds that were undoubtedly making frictional electricity by their motion and discharging the same frequently, was also in great supply. Besides the tearing-down and the up-building processes, there have been the volcanic manifestations which partake of both categories. Very interesting formations of volcanic material are seen in places where regular fracture has given it a columnar

PLATE XVI.

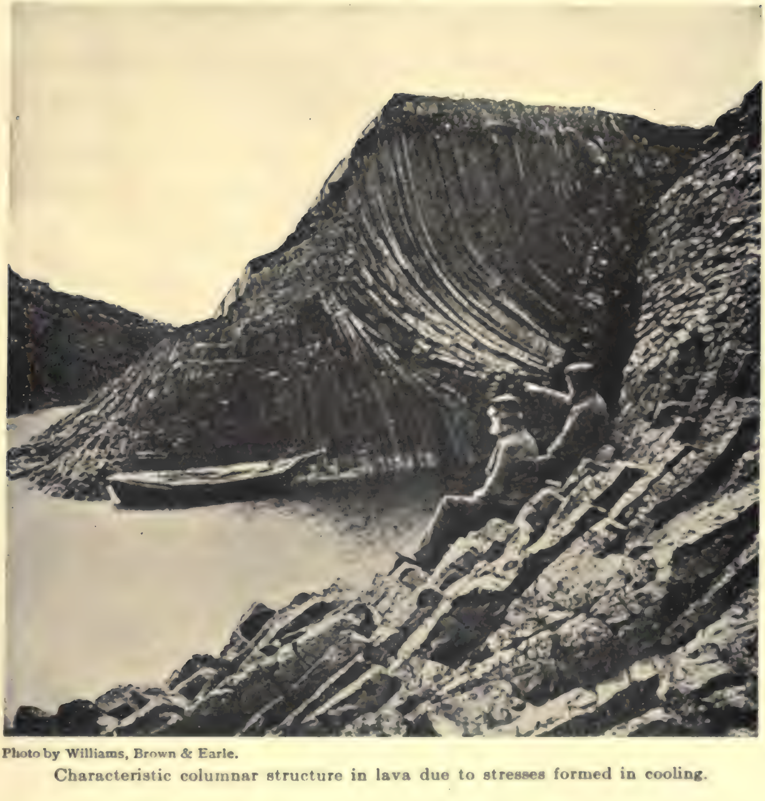


Photo by Williams, Brown & Earle.

Characteristic columnar structure in lava due to stresses formed in cooling.

structure, as in the Giant's Causeway and elsewhere. Volcanic eruptions may have been very important elements in world transformation, but little is known of their real cause and what they have done, although they have undoubtedly been potent factors. There is on the sea floor beyond the reach of continental deposits from the rivers a large amount of red clay that is thought by geologists to have come from volcanic action. This material is richer in iron than clays we find on land, and it does not seem to have come from surface rocks.

The building-up processes are the proper study of geologists, but there is a great deal of chemistry to be considered as well. In the first place, the material worn away by streams has been sorted and collected through long ages in somewhat uniform beds. Coarse sands were carried relatively short distances, coarse clays with sand farther, and the finest clays greater distances, and then deposited. The soluble salts, such as lime, were fully diffused only to be collected by the coral insect and other means and united into great masses and raised to the surface by insect growth, or by the slow rising of that part of the earth's crust.

Geology teaches that in places the crust was lifted and allowed to fall a number of times in succession, so that the same place was sea bottom or elevated land at several different times, as shown by the fossil remains of land or sea organisms. The only way we could have obtained a stratified secondary rock was by the slow accumulations of silt, etc., under water, and then, after it had become compacted by heat, pressure, and liquid and gaseous binding agents, it was lifted by sub-surface forces. In this way clay was compacted to form shale or slate. Carbonate of lime, formed by precipitation from the bicarbonate solution and from insects, was by pressure compacted into chalk deposits, and, where the pressure was great enough, dense and even crystalline limestone was formed. Sandstone is made up of grains of sand, generally cemented together by silica that was not crystalline or was in solution or colloidal[4] suspension. Sometimes it was cemented by means of carbonate of lime, which acted as a binder under heat and pressure. The various secondary rocks are too numerous to deal with here, but they are very interesting. Some of them are nearly as hard as the original granite, because of being subjected to heat from below and the pressure of perhaps tens of thousands of feet of more recent mineral deposits. Frequently chemical analysis will not show the difference between two rocks, one of which is worthless for building and the other valuable, as the difference is all in the compactness. The spaces between crystals or cleavage planes allow of moisture entering, which, when it freezes in winter, disrupts the rocks. When building my house near Philadelphia, a few years ago, there were fragments of rock that seemed quite hard, dug out near the surface of the ground, and pieces lay around all winter. In the spring I noticed in many cases these had crumbled and ready to fall to pieces. The stone below this layer was a very hard and durable quartzite which seemed to have been made by the compacting of a gelatinous silica, and this was used in the foundations. With further reference to personal observations in this vicinity, I have noticed mica schist that was removed in grading roads and put aside for building purposes and after a few winters a large pile of it had almost completely disintegrated. The binder was weak in this stone, as it had not had enough pressure, or had been well on the road to slow decay when quarried. Other nearby stone of similar appearance has had a good reputation for durability, extending over a hundred years. Most people have to use geologically made-over stone for building, as granite is unsuitable for ordinary house use, but one should study the stone and learn its established reputation before using it.

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[4] See definition, p. 315.

In various places, notably in Florida and Tennessee, there are large deposits of phosphate of lime which seem to have come from the bones of fishes and the shells of crustaceans. One of the most useful of the deposits formed by evaporation of prehistoric inland seas is salt, which occurs at depths (where I have observed the location of the strata) of about two thousand feet. It is brought to the surface by letting in water and afterward pumping it out with the salt in solution. Sulphur is mined in a somewhat similar way in Louisiana by the use of steam under pressure.

Suppose nature had not made over the rocks and materials as she has and sorted and concentrated the elements! We would, in that case, probably be leading very primitive lives at this time. The original rocks contained nearly all the elements we have, but not in the convenient forms or concentrated condition we now find them. Then aluminum, lead, copper, zinc, silver, gold, and all the metals were there in small quantities. It would be very hard or impossible to smelt granite to obtain iron or aluminum, or to obtain lime from it in some way. We never would have found the traces of silver and gold. But as the Archæan rock was worn away, these valuable metals and other elements were sorted by solution in solvent waters and precipitated and are now easily available for our use. So far we have dealt with the inanimate creation. At a reasonably early period in geological history, first plant life and then animal life entered into the inheritance, and both of these forms, by their remains, have given valuable deposits that have formed strata with the purely inorganic rocks. Most people know that peat can be used as a fuel. Peat is humus from decaying vegetation.

In one of the early geological periods, called the Carboniferous Age,[5] vegetation grew very rapidly, due to the heat, the moisture, and the carbon dioxide in the air. The dead plants were turned to a kind of peat, and then, with pressure, as the clay, etc., formed above it and with heat from below the solid crust, changes took place that carbonized the material further, and coal was formed. In morasses, perhaps, oil was formed from vegetable remains of smaller growth.

We note stages of these processes at the present time,—the formation of peat as already referred to, and we can now see oil formed in ponds in which organic matter is decomposing under water. Most of us have

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[5] Periods of Geologic Time:

Archæan or Eozoic	
Paleozoic or Primary	Cambrian
	Silurian
	Devonian
	Carboniferous
	Permian
Mesozoic or Secondary	Triassic
	Jurassic
	Lower Cretaceous
	Upper Cretaceous
Cainozoic or Tertiary	Eocene
	Oligocene
	Miocene
	Pliocene
Quartenary or Post-tertiary	Pleistocene or Glacial
	Post-glacial or Human

seen gas bubbles come to the surface in stagnant pools and an oil drop spread over the surface of the water with a play of iridescent colors. The writer's father, Dr. Samuel P. Sadtler, was about the first to show that petroleum could be obtained from vegetable sources. He distilled vegetable oils under pressure and obtained light and heavy petroleum oils. Before this it was thought that it was derived only from animal, if from any organic, sources. The difference between these present-day causes and effects and those of the Carboniferous Era is that of degree but not of kind.

Great quantities of woody matter were decomposed under the most favorable conditions in the making of coal. Whole tree trunks are found fully converted into coal in the veins as they are worked. Analogous agencies probably produced oil and its closely allied substance, asphalt. These matters are only subjects of conjecture, as petroleum oils could conceivably have been derived from the action of water on metallic carbides. In any case, heat and pressure have had decided influence, and much of the petroleum found shows evidences of having been distilled and subsequently caught and condensed to liquid again in strata and localities other than those in which it was formed.

Analyses of different products from the alteration of organic matter by bacterial decomposition, more or less out of access of air, are shown herewith, in the order beginning with wood and going to the alteration products that seem to have had the most heat and pressure. Dr. F. Bergins has made something like anthracite coal by the application of heat and pressure to cellulose, the fibrous substance of wood.

	Carbon	Hydrogen	Oxygen and Nitrogen
Wood	49.31	6.29	44.40
Peat	59.71	5.27	32.07
Lignite	69.82	5.90	24.28
Bituminous coal	85.73	5.49	8.78
Anthracite coal	93.90	3.22	2.88

It is impossible for the writer to recall greater achievements in scientific research than the discoveries of the great geologists, such as Descartes, Lamarck, Cuvier, Lyell, Werner, Smith, Agassiz, and many others, both of the older and the more recent investigators.

CHAPTER XII

SOIL AND ITS CONSERVATION

John Burroughs, in "Time and Change," has said many things like the following so beautifully that the writer is tempted to quote a sentence or two to introduce the present subject: "What an astonishing revelation, for instance, that the soil was born of the rocks, and is still born of the rocks; that every particle of it was once locked up in the primitive granite and was unlocked by the slow action of the rain and the dews and the snows; that the rocky ribs of the earth were clothed with this fertile soil, out of which we came and to which we return by our own decay; that the pulling down of the inorganic meant the building-up of the organic; that the death of the crystal meant the birth of the cell, and indirectly of you and me and of all that lives upon the earth."

The tillage of the soil and the nurture of plants is of great interest aside from its economic importance, and there are but few who do not take some interest in garden or farm work if they have had an opportunity to study its processes. That chemistry has had a predominant part in placing agriculture on an exact basis is well known, and all successful farmers and truck raisers make use of chemistry.

PLATE XVII.

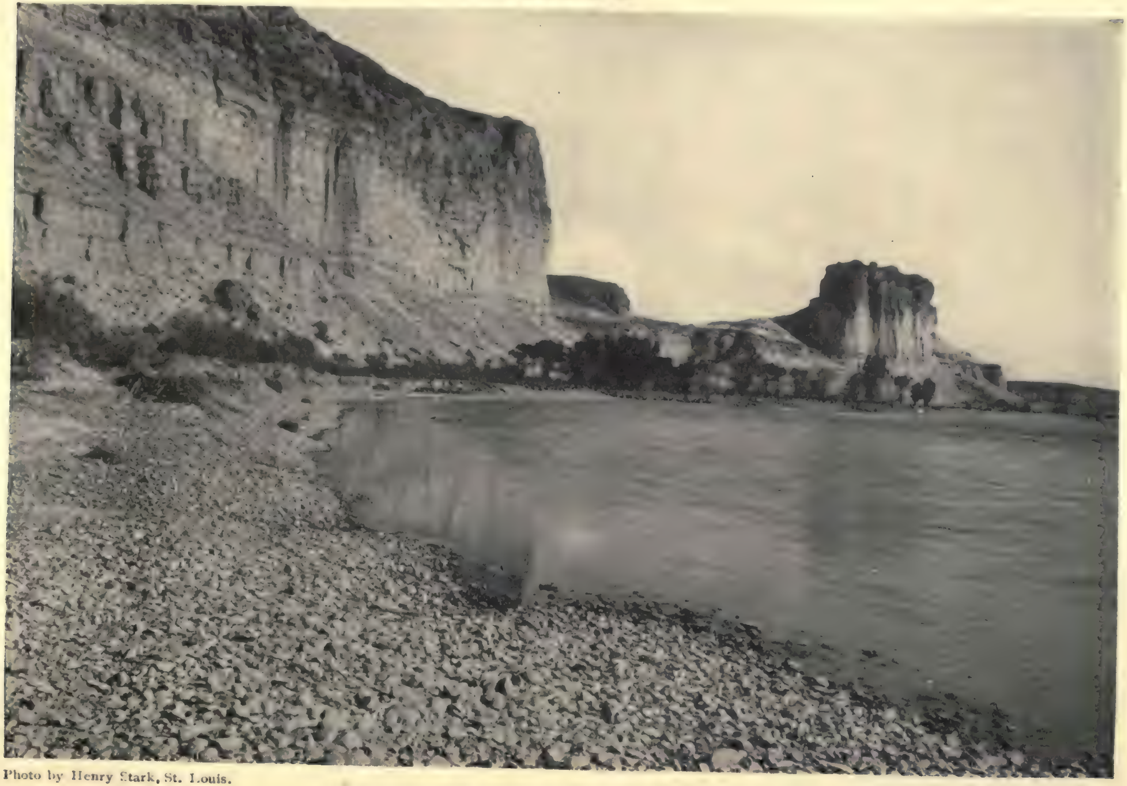

Photo by Henry Stark, St. Louis.

Buttes of the Green River, Arizona, showing stratified rock.

Soil is made up of weathered or decayed rock and organic matter. Soil may come from the weathering of local rocks or it may be carried by glacial action from distant points or by streams from higher levels. In the first instance the soil is known as sedimentary, and, in the second, alluvial or transported soil. Practically all rocks weather, especially while in their native locations. Some rocks, such as granite, when dressed and placed in buildings, do not seem to weather to any appreciable extent, but they are not subjected to all the influences of surface outcroppings as in natural situations. All rocks have more or less spaces between particles or portions of the rock. If large, they are cracks or fissures, and if very small, they may be only the spaces between individual crystals. The main influences of soil formation are:

A. The freezing and thawing of water in the interstices of rock.

B. The action of carbon dioxide and water on limestone[1] and feldspar.[2]

C. The similar action of humic acid on limestone and feldspar.

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[1] The carbon dioxide unites with the limestone or calcium carbonate to form dicarbonate, which is soluble in water. Thus, $CaCO_3 + CO_2 + H_2O = CaH_2(CO_3)_2$.

[2] Feldspar is a silicate of sodium or potassium and aluminum. The water assisted by the carbon dioxide dissolves out the sodium or potassium and leaves aluminum silicate or clay, thus $2KAlSi_3O_8 + 2H_2O + CO_2 = H_4Al_2Si_2O_9 + 4SiO_2 + K_2CO_3$, as a powder in place of the dense crystalline mineral.

D. The disintegration of rocks by means of the roots of plants.

E. Splitting by alternate expansion and contraction due to heat and cold.

F. The physical deflocculating (pulverizing) effect of soluble organic matter on clay.

Every one has seen fragments of rock with bright glassy fragments of quartz or silica associated with slightly duller particles and others black in color. The less glassy white or pink places are likely feldspar, which weathers to clay, and the black mineral particles, on weathering, make the clay reddish, due to iron oxide.

As the rocks break up, clay is formed from feldspar, and particles of silica are separated and form sand, especially after they have been split up into smaller pieces by changes in temperature, etc. We often see strata of rock in cliff faces or railway cuts where the rock is perceptibly crumbling and becoming soil. Sometimes the change is so slow that one does not notice it. In other instances we can from season to season note the changes wrought by nature. If all the surface soil were removed to the underlying rock at any point, the agencies of mineral decay would in a few years or centuries, or other periods of time, produce the accustomed result of soil formation. In almost all the advanced stages of this decay we can see the particles of silica (sand) or mica separating from the decomposing rock. This soil production is noticeable in the very early spring. In many cases there are small avalanches of decomposed rock running down over snow-banks from the rock faces above. This is particularly noticeable in railway cuts in February or March.

Burroughs refers again to the soil in his beautiful yet terse manner: "The history of the soil which we turn with our spade, stamp with our shoes, covers millions upon millions of years. It is the ashes of the mountains, the leavings of untold generations of animal and vegetable life. It came out of the sea; it drifted from the heavens; it flowed out of the fiery heart of the globe; it has been worked over and over by frost and flood, blown by winds, shovelled by ice—indeed, the soil itself is an evolution, as much so as the life upon it."

Sand in its purest form is silica, but any fine pieces of rock are familiarly known as sand. The chief practical difference between silica sand and other sand is that silica is not very alterable, whilst complex silicates are liable to disintegration. Sand is generally white unless it contains iron.

Clay and sand are two essentials of soil, and we have just seen how they are formed. Other minerals than silica, necessary to soil formation, contain lime, iron, magnesia, phosphoric acid, potassium, sodium, manganese, sulphates, chlorides, etc., which are needed to sustain plant life. While all the mineral substances just mentioned are necessary for proper plant development in general, it has been found that there are three substances that no plant can do without. They are potassium salts, phosphates, and nitrogen, chiefly in the form of nitrates. The first two of these substances are supplied from rock sources and exist in the soil chiefly as more or less fine rock particles and a smaller amount in water solution. The nitrogen comes directly or indirectly from the air. The particles of rock containing these valuable fertilizing substances are the reserve store, while the soluble quantities are for immediate use.

From time immemorial it had been known that soil continuously cultivated, especially by one crop, became exhausted, but the reason was not known for a long time. Although in the more recent periods it was known that plant substance contained mineral matter, it was thought to be incidental. Of course, ground was cultivated and in a way it was fertilized, but the reason for the latter was not clear. Farmers knew that if the ground lay fallow a year it would produce more, or that if the crops were rotated it would produce regularly, especially if animal and vegetable refuse were used on the fields. It was the great German chemist, Justus von Liebig, who first realized that plant life always withdrew certain constituents from the soil, and showed that if the most fundamental mineral foods were restored there would not have to be periods of idleness to rejuvenate it.

Clay alone would not constitute soil. Sand alone, and even clay and sand, would not constitute soil. A third essential ingredient is the decomposed organic matter or plant residues (roots, etc.) that have become degraded and form the so-called *humus*. This is another of the many evidences of nature's conservation of her resources. Plants grow, bloom, are reproduced by seeds, etc., and the old tissues rot in the earth as they are pressed into the soil, and, as soil constituents, form new and never-ending cycles of beauty and usefulness. The value of humus lies chiefly in its water-holding capacity. It gives a dark color to the soil, which would otherwise be white or shading to red, due to the presence of iron. Leaf mould and wood earth are largely humus unless they have become mixed with clay soil. The work of worms and insects effects a mixing of all components.

Lime is chiefly of value in that it neutralizes the acid qualities of the humus or humic acids, as the acid principles of humus are sometimes called, and as an additional property, or because of its neutralizing the humus, it tends to granulate the clay and thus make it more valuable. A good soil, therefore, is a combination of clay, sand, humus, lime, and other mineral constituents, such as potassium salts and phosphates. Generally speaking, good soils are a little richer in sand than in clay, and if there is over 50 per cent. of clay the soil is stiff to work. Very sandy soils may have only 15 per cent. of clay. The pore space should be 30 to 50 per cent. by volume. The volume of pores may be determined by filling a quart measure with soil and noting how many fluid ounces of water can be added without overflowing, after air has been displaced.

Soils are examined in various ways to determine their composition. Their fineness is determined by sieving when dry, and their capacity for water, both hygroscopic and total, and pore space are estimated. They are chemically examined for humus, lime, potash, and phosphoric acid, and these tests might be followed by examination for bacteria in special cases. It has recently been found that manganese has an important catalytic effect upon plant growth. Gabriel Bertrand, in France, found that with the use of 22 to 52.8 pounds of manganese sulphate per acre various crops were increased from 10 to 33 per cent.

In addition to the mineral substances mentioned previously,—namely, silica, alumina (from clay), magnesia, iron, lime, sulphur (from sulphates), phosphorus (from phosphates), and potassium,—plants require carbon, hydrogen, nitrogen, and oxygen. The carbon comes from carbon dioxide in the air, the oxygen directly from the air, and the nitrogen also comes from the air after being converted into nitrate by means of bacteria.

There are many times as much necessary mineral foods for plant life in practically all soils as the customary crops require for a season's growth. It may average from 50 to 100 times the quantity, but the entire amount is only slowly made available by the action of carbon dioxide gas or its weak union with water, which is called carbonic acid, and possibly other agencies. Carbon dioxide is always coming off from cultivated soil as it is formed from decomposing organic matter. A little of it is used before total elimination to free the phosphoric acid and to break up the feldspar, thus forming kaolin (clay) and soluble potassium salts, and the rest of it comes from the surface of the soil, and, because of the fortunate provision of nature in giving a greater weight to this gas than air, it tends to stay close to the ground, where the plants can absorb it with their leaves to best advantage and thus obtain the carbon they need for their growth. There is thus the two-fold value of plowing under plant refuse,—it forms humus which retains moisture and it gives off large quantities of carbon dioxide to feed the tops of new plants. Even for lawn grass, when the mowing is done frequently before it has grown more than two or three inches, it is beneficial to let the tops fall and make humus around the roots, and there will be less danger of the grass being killed or parched in dry weather. From time to time, however, most soils require lime to neutralize the humic acids formed, making neutral salts, which might be called calcium humate. This soluble organic matter is undoubtedly valuable in loosening the clay aggregates, or deflocculating it, as Acheson does his graphite for lubricating purposes.

Ways to tell when soil is very acid are: (*a*) It turns moistened blue litmus paper quickly red; (*b*) the soil tends to be dense rather than crumbly; (*c*) weeds grow very rankly. As bacteria will be shown to be needful for plant life, and as scientists have found that in most cases useful plants develop better in neutral than in acid media, it is in every way desirable to keep the soil nearly neutral. Keeping soil neutral is easier done on high ground than in low, where organic acids from decomposing vegetable matter remain instead of being split up into carbon dioxide gas and water.

We have to depend largely upon nature to supply what is needed for the growth of plants, and her part is done wonderfully well. There are few parts of the United States that do not have sufficient rainfall for bountiful crops when care is taken to conserve the moisture during moderately dry as well as in the very driest seasons. If it is conserved during moderately dry seasons, the problem is less difficult in the driest period. There are also few sections of the country where rains are so frequent that no care need be exercised to conserve water. The soil holds water very well for plant use when loose and open, but if packed and the grains of clay and sand are in close proximity, water comes up to the surface by capillarity too rapidly and passes off into the air. Every one has observed the phenomena of capillarity in the home—(*a*) how the blotter absorbs ink; (*b*) how a sponge absorbs water; (*e*) how oil rises in a wick; (*d*) how a dry cloth laid in a basin of water will become wet, and, if the cloth extends over the edge of the basin and hangs down, water may drop from the end.

Soil moisture and the soil atmosphere play a very important rôle. Moisture in the soil normally is only on the surface of the particles. When the soil is saturated, however, it sinks by gravity and draws down the soil atmosphere, rich in carbon dioxide. The carbon dioxide dissolves in water, and this acid solution attacks the feldspar and lime rocks. When the soil dries out at the surface the soil solution rises by capillarity with fresh mineral salts in solution. Moisture will steadily pass off from the soil by evaporation after a rain, but, if the soil be pulverized a day or two after the rain and stirred up from time to time, enough moisture will nearly always remain until fresh rains come. The amount of water plants use that is not in their substance at maturity is enormous, probably a hundred times that used. Large-leafed plants such as cabbages will give off tons of water per day per acre, and this and more must be found by the roots. Plant roots will seek the best water levels, and in dry weather a little surface watering will do more harm than good, as it will tend to make the roots turn up to the moist surface layer instead of continuing a downward growth.

Analyses are often made of a soil to determine the available and total potassium salts, nitrates, and phosphates, and the results are valuable only when applied to a particular soil and locality. Two fields on the same farm may have equal fertility, with different amounts of plant food, because of the different character of the soils. The following figures are probably approximate percentages of the chief constituents of plant food in good soil:

Plant Food	Symbol	Percentages
Nitrogen	(N)	0.16 to 0.20
Phosphoric acid	(P_2O_5)	0.20 to 0.40
Potash	(K_2O)	0.40 to 0.50
Carbonate of lime	($CaCO_3$)	1.00 to 3.00

A good rule in fertilizing is to add to all ground such an amount per year of manure or fertilizer that the available plant food shall not diminish. Fertilizers are generally turned under the ground to prevent their being washed away and to be where required by the plant roots. It is difficult, however, for water to wash away fertilizing constituents when mixed with earth, for a reason to be considered. Enormous loss is sustained annually in the United States and other countries by soil erosion where the best loam is carried away by the streams and rivers, but it is a case of bodily removal of soil and not a case of dissolving out potash and phosphates. If the soil did not have a property whereby it could hold the valuable constituents, the rains would wash all the fertilizing elements out of the soil, and the underground streams which emerge at low levels, as springs, would be rich in plant food. Water analyses do not show this. There are various proofs that show this property of the soil for holding plant food, which is called *adsorption.*[3] For example, many people, including the author, have drunk very pleasing water drawn from artesian wells within a few feet of the ocean itself. Why is it not brackish? Chemists have found that clay and fine sand have some kind of a physical or chemical attraction for these soluble salts. So the water can pass through the soil and leave the soluble substance for plant nourishment.

The most important consideration of the farmer and the truck raiser, and one of the most practical for the amateur agriculturists, is the study of fertilizers to determine the best to use under general and special conditions. Those much interested in the study of fertilizers can secure all the information they may require from State and national authorities, as Bulletins have been published from time to time that go into all phases of the subject. The Secretary of Agriculture will send lists of publications to those who request them. State and national laws on this subject have put the sale of fertilizers upon a perfectly plain and fair basis, as it is required in this country that the percentages of the active ingredients be marked on each bag or package. Competition has made the prices proportional to the composition.

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[3] See definition, p. 314.

The three primal requisites for plant growth, other than suitable soil and proper cultivation, are potassium, phosphoric acid and nitrogen, chemically combined. There are a great many kinds of fertilizers and all are sold at so much per unit of each ingredient. The best-known and probably most-used fertilizer is ordinary barnyard manure. It does not contain as much plant food as the best commercial fertilizers, but it is very effective because of the organic matter it contains, which dilutes the active substances and tends to form a soil rich in humus (bordering on bituminous matter). Any fertilizer in concentrated condition is liable to kill plants if it gets in their roots, as any very strong chemicals would do. A very concentrated form of natural manure is sheep manure. Guano from Peru is a fertilizer consisting of the manure and decomposed carcasses of sea-fowl, much used in the past but fast being superseded by artificial fertilizers. Fresh, dry, ground carcasses of fish are used chiefly for their nitrogen. Bone meal is chiefly valuable for phosphoric acid and nitrogen, while leather scraps and powdered hoofs and horns are used for nitrogen alone. The most concentrated fertilizers for supplying nitrogen are nitrates of soda and lime, and ammonium salts. A few analyses of fertilizers are given in the footnotes.[4]

In a few words, the effects of the several ingredients of fertilizers are: nitrogen (ammonia) causes rapid vegetation; phosphoric acid and potash are needed for the plant cells and sap, and must be supplied as required. Nitrogen may be supplied as organic matter, as in fish remains (protein nitrogen), as ammonia, and as nitrate. Phosphoric acid (P_2O_5) comes in artificial fertilizers as an acid calcium phosphate, which is made by adding sulphuric acid to phosphate rock. Part of the phosphoric acid in commercial fertilizers is soluble, part insoluble, and another part is called reverted, which slowly becomes soluble. It, of course, is only valuable when soluble or slowly available in the soil.

The importance to the farmer of saving the liquid portion of the manure is shown in the following extract

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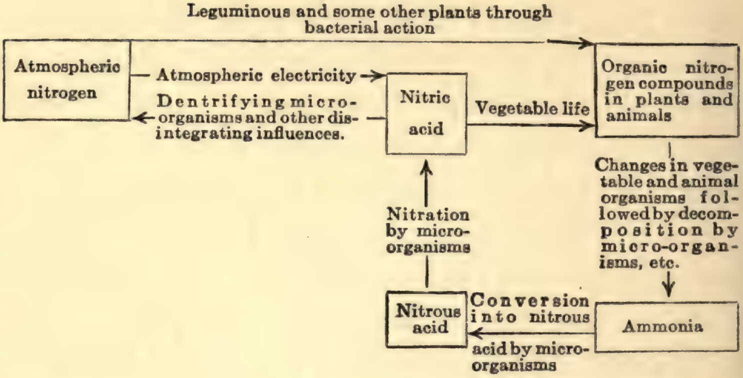
	Phosphoric acid (P_2O_5)	Nitrogen (N)	Potash (K_2O)
[4] Farmyard manure	0.50 per cent.	0.50 per cent.	0.30 per cent.
Peruvian guano........	12.14	9.14	1.00
Dried fish...............	10.15	6.12	
Sodium nitrate		19.00	
Oil cake (castor)	1.5 –3	4.7	1.0 –2.0
Bone meal	20 –30	2.5	
Mineral potash			65 –70
Phosphate rock	30 –40		

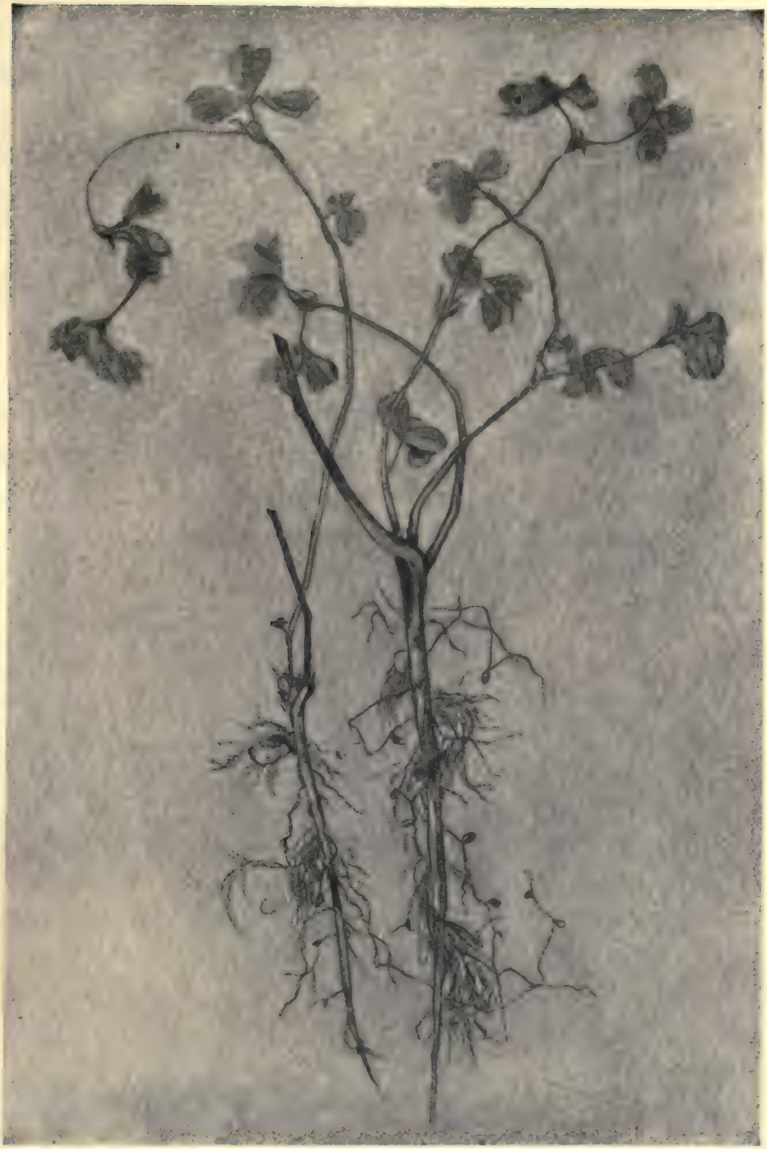
from a pamphlet published by Dr. Samuel G. Dixon, Health Commissioner of Pennsylvania: "If you do not retain the natural liquids and those dissolved out by the rains, your crops will fall short or you will have to take the money and purchase artificial fertilizers which do not take the place of good, well-kept manure. You will not get the humus, nor will you keep up the biological standard and general physical conditions of your soil. If you will keep the manure in water-tight pits, well packed and moist, your expenses will come back to you tenfold, and at the same time you will be your brother's keeper by preventing your sewage from getting into his water supply and making him sick with, maybe, one or another of many intestinal diseases. You can co-operate with the health authorities, make more out of the land and save others and yourselves much sickness, sorrow,—yes, death."

The final consideration under this subject is that of the bacteria and larger forms of organisms of the soil. We have known for some time that worms loosen up the soil and distribute the plant food. Their influence is probably chemical as well as physical by supplying soluble organic matter. The chief consideration here, however, lies with the millions of bacteria that are at one time found in an amount of soil of no bigger volume than a moderate-sized earthworm. From 500,000 to 1,000,000 bacteria are found in summer in a single grain weight of soil. Besides bacteria, there are yeasts, moulds, fungi, protozoa, amœba, nematodes, and, finally, worms. Some of these organisms are so small that the most powerful microscopes can only see them under favorable circumstances. The protozoa and amœba are larger than the bacteria, and the nematodes are very small worm-like animals. The reason all these are mentioned is because they all have chemical influence on the soil. Some are the prey of others, so that the numbers of each variety are limited by their racial fights for existence. The yeasts, moulds, and fungi are probably mostly concerned with the first steps of the reduction of organic matter to humus. The most important cycle of operations is in the change of protein (nitrogenous organic matter), first by one set of bacteria into amino acids, then into ammonia by another group; another group form nitrites from the ammonia, and, lastly, others, called nitrifying bacteria, change the nitrites into nitrates, which are utilized by the plants. This cycle of change is dependent upon a proper balance of animal life in the soil, which is dependent upon the existence of all the organisms mentioned and upon moisture, warmth, and aëration of the soil. If the ground is watersoaked, there flourish a set of bacteria which are denitrifying. Therefore, it is very necessary to have the soil open so that air can get in to aid the nitrifying bacteria.


Leguminous and some other plants through bacterial action
Atmospheric nitrogen
Atmospheric electricity
Dentrifying micro-organisms and other disintegrating influences.
Nitric acid
Vegetable life
Organic nitrogen compounds in plants and animals
Changes in vegetable and animal organisms followed by decomposition by micro-organisms, etc.
Nitration by micro-organisms
Nitrous acid
Conversion into nitrous acid by micro-organisms
Ammonia

There is another important kind of bacterium that is not concerned in this nitrogen cycle, but seems to have a new and improved process for making nitrates. Instead of employing three or more races of bacteria to make the desired chemical, these recently discovered bacteria make it apparently by themselves, directly out of the nitrogen and oxygen of the air. Their life is distinctly apart from the dense and the heterogeneous world of soil life, as they are housed in cavities and nodules formed in the roots of certain plants, chiefly the leguminous plants, such as peas and beans, and also in clover and alfalfa. These bacteria not only greatly assist the growth of these plants, but, due to the excess of nitrates formed over what the plants use, the ground is more fertile after these crops are grown than before. This is one reason why clover is a good crop to alternate with grain. Barren soils can be improved by an inoculation with these bacteria by spreading in the place desired

PLATE XVIII.



Drawn by A. H. Sadtler.

Alfalfa, showing root nodules encasing nitrifying bacteria.

some soil from where these nitrogen-fixing bacteria have been abundant. About half a ton of this soil per acre is sufficient, which amounts to a mere sprinkling. Cultures from growths in gelatin are also used as seed instead of spreading soil. It may take several years before the benefit of this inoculation is apparent.

There are bacteria in the soil that do not exactly concern the chemist, but a few words may be said about them here. The bacillus of tetanus is found in the soil, particularly in layers below the influence of the sun's rays. The same is often true of typhoid and diphtheria bacteria. The former has been known to flourish and spread in damp, dark, warm soil. Well cultivated, aërated soils are inimical to these bacteria, as sun and air are fatal to their growth.

Night-soil and cesspool contents should not be used in truck patches, because of the nearness to the house, the danger to persons working in them, the danger of contaminating green, uncooked vegetables, and the nearness to wells which this matter might pollute. Their benefit would be slight and the risk of their use so great that the fertilizing value might as well be entirely ignored.

The regular growth of the plant is very much the same as it is with animals, although the means of nutrition are different. In the young plant, sprouting from the seed, the starch, protein, and fat stored there feed the growing stem and branches so long as the food lasts or until there is enough chlorophyll to make the food in the leaves. Plants have to form their own food from the air with the aid of chlorophyll from the energy derived from the sun's rays in conjunction with water of carbon dioxide and inorganic salts. The carbon dioxide of the air and water make formaldehyde. The condensation of formaldehyde produces the sugar which is changed by plant enzymes into starch, pectin, or cellulose. The nitrogen of the air is changed by bacteria into nitrate, which the plant changes, probably in its roots, to protein material, although it may be that nitrogen is also absorbed by the leaves to form protein.

CHAPTER XIII

FOOD ELEMENTS AND FOOD CLASSES

ANIMALS depend, in general, upon vegetation for their food, although some animals take short cuts and save time in eating and in digestion by consuming flesh itself. Animals get only salts and water from inorganic sources.

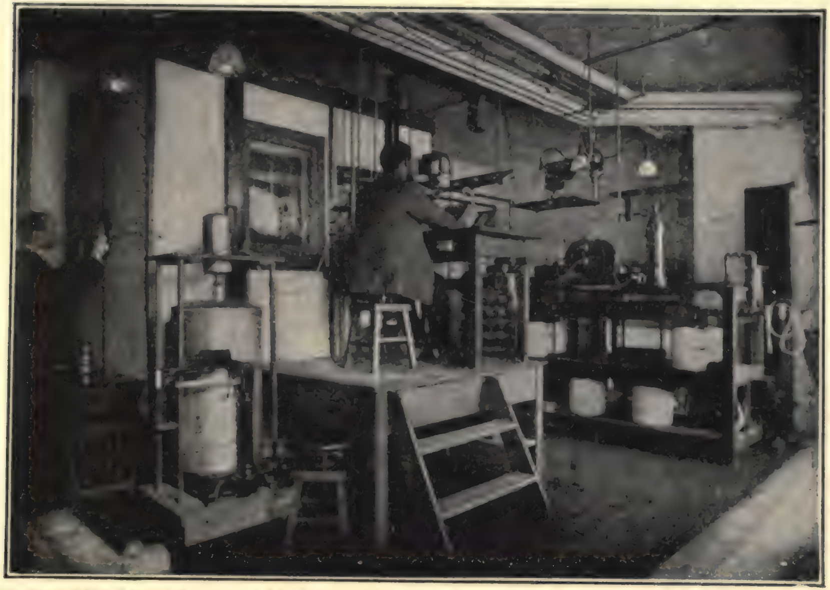
The natural inclination or instinct and the experience of countless past generations have shown us what to consider as food. The chemist in most cases confirms the reasonableness of the selections made and shows from his analyses and tests which foods are best for special requirements. Chemistry is important in detecting impure and adulterated foods.

Food is required to supply the force for the unconscious work of pumping the blood and breathing and also the requirements of the voluntary muscles, and, as incident to these activities and independent of them if need be, to supply heat to maintain the body temperature of 98.6° F. With some difficulty we can maintain our houses at fairly uniform temperatures, but we never succeed to the fine point that is maintained in our bodies,—accurate to a tenth of a degree. Of course, this is only accomplished by means of an absolutely dependable automatic regulator, as we normally replenish the bodily fires with fuel only three times in twenty-four hours and yet the temperature does not vary.

The exact way food acts to create heat in the body has been shrouded in some mystery, because of the different classes of food materials which create heat. Protein material is quite different chemically from carbohydrates, and fat is another class differing from the other two, yet all three classes are capable of producing heat. It would take too much space even to outline the different theories that have been advanced to solve this wonderful cycle of change in the assimilation of food and creation of heat and energy. We know these substances are more or less interchangeable, except that only protein can form muscular tissue and repair the same.

It has been found possible to measure the heat that food substances are capable of forming on combustion with oxygen in two ways; both consist in the use of *calorimeters,* or heat-measuring instruments. One way is outside of the body, in which a very small but definite weight of the dry food substance is burned in oxygen and the heat formed is absorbed in water and measured by the consequent rise in temperature of the water. The other way is by the use of a calorimeter so large that a man can be contained in it, and, as he eats,

PLATE XIX.



Courtesy of United States Department of Agriculture.

Human calorimeter.

sleeps, moves, reads, etc., the heat that is radiated from his body is measured by delicate thermometers. Of course, unavoidable heat losses are measured, so that the calculation may be dependable. In the illustration opposite page 178 the calorimeter holding the human furnace, the heat of which is to be measured, looks like a closet with a window in it to the left of the cut.

Digestion consists of a series of chemical changes which are designed by nature to dissolve the food or mechanically emulsify it with water, as food must be dissolved or emulsified to be assimilated, and the cells of the body are composed largely of water. Water is an important food or food accessory. As S. Solis Cohen has said, "The cells of the body are aquatic in their habit." Sixty to seventy per cent. of the body is water.

In nearly every process of digestion the change is brought about by substances, called *enzymes,* made in glands of the body. Enzymes do similar work of digestion in the vegetable world. We all know of the enzyme called diastase in the young shoots of barley. Of course, there are enzymes in all young shoots from seeds. These enzymes digest the starch in the seeds, say of barley or corn, and convert it into soluble sugars, which are carried through the tissues of the young plant and deposited as pectin or cellulose to form the skeleton or framework of the plant. After the leaves are formed this starch is not needed, as carbohydrates are built up from the carbon dioxide of the air and water by the influence of sunlight and in the presence of the catalytic substance known as chlorophyll, or the green coloring matter of the leaves. A catalytic substance is one which induces a chemical change without entering into the reaction itself by giving any component to the new substance formed. Enzymes are of this general character.

The different food classes are digested differently. *Starch,* which is the most important food member of the carbohydrate family, is acted upon first in the mouth under the influence of ptyalin. According to Davis,[1] this action is retarded by cold liquids and acids. Water had best not be taken in quantity during the mastication of carbohydrates, and acid fruits should rather follow than precede the meal. In most cases the food is not in the mouth long enough for much digestion to take place, and no change in starch is effected in the stomach except mechanical disintegration, due to agitation and the attack of the stomach juices upon the protein. Carbohydrates are chiefly digested in the small intestine by *amylopsin,* an enzyme. All carbohydrates finally are changed into dextrose, which enters the blood.

Fats and *oils* are acted upon by the pancreatic juice (pancreatin) and are then saponified and emulsified in the intestine by the enzyme steapsin. They are carried by the blood to the places where deposited or stored for continual combustion to carbon dioxide and water and liberating their definite quantities of heat during the process.

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[1] "Dietotherapy and Food in Health," by Nathan S. Davis.

In the case of protein digestion no change is effected in the mouth. In the stomach acid albumens are formed by the hydrochloric acid of the gastric juice and then all are changed into peptones by the action of pepsin. What protein escapes digestion and absorption in the stomach is formed first into alkali albumen at the entrance of the intestine and then acted upon by the enzyme trypsin, to complete the digestion and allow of the absorption of the food elements. There are various influences that the different kinds of food have upon each other during digestion. If protein food is taken alone and escapes digestion in the stomach, a good deal may be lost by bacterial decomposition in the intestines, which are in large part alkaline and favor bacterial activity. The use of mixed diet with carbohydrate food minimizes this occurrence, as acids are formed during the course of digestion of carbohydrates which render the intestinal tract acid. This inhibits the growth of organisms that would live at the expense of the protein. A fetid odor of the intestines is often an indication of bacterial putrefaction of protein matter therein, due to a too exclusive meat diet.

Fat influences the digestion of protein and carbohydrates by enclosing particles so that the aqueous juices do not readily attack them. This is the chief reason why fried food is often indigestible. Readily emulsifiable fats, like butter, cream, and olive oil, are not so detrimental to proper protein and carbohydrate digestion, as they are easier separated by the steapsin.

Protein is the food substance or class of substances containing nitrogen, such as lean meat, the albumen of eggs, the albumen and casein of milk, and that part of dry vegetable substances which is not oil, carbohydrate, or mineral matter. *Carbohydrates* are substances that do not contain nitrogen, and are not fats and oils. They contain carbon and hydrogen, with enough oxygen to form water with the hydrogen. As hydrogen could only give energy by burning to form water, the only energy that carbohydrates have is the potential energy of the carbon. *Fats* are glycerides of organic acids. They contain no nitrogen, but have both carbon and hydrogen susceptible of oxidation. For this reason they create more energy in the body than protein or carbohydrates.

The natural selection by mankind has indicated to investigators the best combination of food elements. Experiments with a wide range of combinations have also shown that this certain ratio of natural selection is really the most practical and physiologically the most economical. This ratio is approximately:

Fat	1.0 part by weight
Protein (digestible)	2.4 parts by weight
Carbohydrate (digestible)	10. parts by weight

To this must be added the requisite quantities of water and mineral matter. The ratio of fat, protein, and carbohydrates varies somewhat from infancy to old age. More protein is required in the young to effect growth than in the mature, and in the case of the aged there is so little muscular action that extremely little protein is required. Lime salts are required in abundance by the young to make bones, while with the fully grown very little are needed.

Nature provides the proper food for the young of all species, and where milk from the mother is supplied it has a composition that enables the young to develop properly.

COMPOSITION OF MILK.

	Cow's milk	Human milk
Water	87.3 per cent.	87.4 per cent.
Fat	3.6 per cent.	3.78 per cent.
Protein	3.8 per cent.	2.29 per cent.
Milk sugar	4.5 per cent.	6.21 per cent.
Acid	0.1 per cent.	none
Ash	0.7 per cent.	0.37 per cent.

Cow's milk can be given to infants, but modification is desirable. It is generally diluted; cream is sometimes added to supply more fat; milk sugar or cane sugar is added and the free acid is neutralized with lime water. The calf, for whom cow's milk was intended, is expected to grow much faster than the child; consequently it gets more protein to make tissue and more mineral matter to make bone and less carbohydrates. Lime water is added to neutralize the free acid in cow's milk that has come from bacterial action, although the fresher the milk and the cleaner the dairy the less acid to be neutralized. It might be asked, "What is the function of the barley water or starchy liquid from oatmeal, etc., that is sometimes used?" This is added to prevent dense clots in the stomach when the milk is curdled by the acids of the gastric juice. Chemists call such an added substance a "protective colloid." Gelatin is a protective colloid and makes ice-cream smoother. The albumen in human milk protects the casein from precipitation or curdling.

There is no one article of food that combines all that is requisite to the system. One could not live very long on nothing but carbohydrates nor on fat alone. If a person takes a good deal of exercise he might get along on nothing but meat, but for most of us it would be unsuitable. A purely vegetable diet would serve better than one of meat alone, as some vegetable foods are nearly balanced in the nutritive ratio. Bread has sufficient protein, carbohydrates, and mineral matter, but lacks fat; however, if it is spread with butter the ratio is about right. Most people in good circumstances in this country eat too much protein. A table from Olsen gives rations of people in some various lines of activity. The writer does not wish to exaggerate the importance of a knowledge of total calories required from the combustion of food and of balanced rations, as most people in easy circumstances get along better if they do not indulge their appetite so freely, but for the benefit of the poor and less well informed much good might be derived from more light on this subject. Men suffering with hunger will pay their last piece of money for a cup of coffee, with but a trifle of nourishment, when they could get rolls, baked beans or meat stew with more food value and derive real benefit.

Special Rations

Age or employment	Protein	Fat	Carbohydrates	Calories
Average adult	100 grammes	100 grammes	420 grammes	3030
Average of seven boat crews	181 grammes	177 grammes	440 grammes	4085
Foot-ball team	181 grammes	292 grammes	577 grammes	5740
United States Army	85 grammes	280 grammes	500 grammes	4944
Old man	92 grammes	45 grammes	332 grammes	2149
Old woman	80 grammes	49 grammes	266 grammes	1875

The average man requires food that will give about 3000 calories per day. Children from one to two years of age require 24 per cent. of the food to be protein, while adults need only about 16 per cent. This is due to the necessity of the child to add to its tissues as well as repair them.

Another table, largely from Olsen,[2] gives the amounts of various single food substances that will give this energy or fuel value, and the cost of each:

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[2] "Pure Foods," by J. C. Olsen.

COST OF A DAILY RATION OF A SINGLE FOOD PER PERSON.

Food	Price	Cost of 4000 calories
Flour	3½ cents per pound	6.3 cents
Oatmeal	5 cents per pound	8 cents
Rice	8 cents per pound	15 cents
Sugar	5 cents per pound	8 cents
Beef	20 cents per pound	58 cents
Milk	9 cents per quart	20 cents
Eggs	40 cents per dozen	184 cents
Cheese	18 cents per pound	26 cents
Fish	14 cents per pound	101 cents
Potatoes	80 cents per bushel	12 cents
Cauliflower	15 cents per pound	215 cents
Onions	14 cents per pound	215 cents
Strawberries	13 cents per pound	250 cents
Butter	35 cents per pound	29 cents
Olive oil	250 cents per gallon	23 cents
Bananas	15 cents per dozen	40 cents
Oysters	12 cents per dozen	553 cents

Food materials are not completely absorbed, although some are normally nearly all utilized. Animal foods are better digested than vegetable foods, with the exception of sugars, which go very quickly into the circulation. This is assuming no excess of meat is taken. The protein of cereals, however, is quite fully absorbed if the cereal is well prepared by cooking. This is in contrast to peas, beans, and lentils with digestive coefficients of only about 80, the proteins of meat being about 98 and bread 90.

Green vegetables are more in the way of regulators than foods, as the large amount of waste serves to excite peristaltic movement in the intestines, but the use of very large quantities may be bad in two ways: they tend so to dilute the contents of the stomach that the digestive juices do not have full opportunity to act on the important food elements, and because of too active peristalsis the food may be hurried on too rapidly. One detriment to an exclusive vegetable diet is the lack of flavor, the presence of which would cause better secretions of the digestive enzymes. The extractives or amines of meat excite the flow of gastric juice and pepsin, which are needed to act properly upon proteins. In the case of starchy foods this is not necessary, as they are not acted upon in the stomach. People requiring comparatively little food may get along fairly well on a vegetable diet. But for an active life meat is a valuable part of the diet, and if on the score of economy very little meat is available, the addition of the meat extractives from bones to make soup will excite the secretions very well.

One may eat slightly less food in summer than in winter on account of less necessity of generating heat, but the difference is slight, as the variation in weight of the clothing and the heating of the houses makes up some of the difference. The chief factor at all times is the amount of exercise. More fat should be taken in winter than in summer, as it is the prime heat producer. It is astonishing how much work an average man in good physical condition can do. It is stated that a hard day's work would consist in raising his own weight

10,000 feet, or the expenditure of 1,400,000 foot-pounds of energy. As the equivalent of 1 calorie in mechanical energy is 3077 foot-pounds and a man gets 3000 calories in his food, if all were available for work he could perform work to the extent of 9,000,000 foot-pounds, or 4500 foot-tons. As it is, the efficiency is about one-sixth, or is distinctly more efficient than a steam boiler, which is hardly over one-eighth.

Most foods are better for being cooked. If cooking did not do anything else, it would be very valuable in its effect in sterilizing food or killing bacteria, moulds, and even parasites. The second effect in its general benefit is that it makes the food more palatable, which is something of vital importance in digestion. When food is cooked it is sterilized on the exterior, but in many cases it is not heated enough to sterilize the interior. Roasts of meat are still rare enough inside to indicate that the heat has been far short of sterilization. The writer has frequently tested bread in the centre of the loaves and found lactic-acid bacteria.

Some foods are improved in digestibility by cooking, while others are more digestible before cooking. Starchy vegetables and those containing much cellulose belong to the former class. Very tender meat and some vegetables and fruit not containing starch belong to the latter. *Meat* would be more digestible raw if it were not too dense for satisfactory mastication. Sometimes meat scraped from connective tissue is warmed and served on toast, etc., to invalids, in which case it is most easily digested. Cooking sterilizes the surface of meat, which is the only part very likely to contamination, renders it more palatable, and in many cases makes it more easily attacked by the digestive juices by softening the connective tissues. *Starchy* and fibrous vegetables are made more digestible and in most cases more palatable by cooking. The starch granules are ruptured by boiling or changed into soluble dextrin by dry heat or into sugar by moist heat and acids. *Fruits* that especially need cooking are bananas and green apples on account of starch. Pineapples, roots, and some varieties of pears, etc., need cooking on account of cellulose. As nearly all vegetables contain starch or woody fibres, practically all of them need cooking. Lettuce and tomatoes are exceptions. Celery has a good deal of fibre, but it does not seem to enclose starch, so boiling it is optional.

A great deal of cooking is carried to too high temperatures. Protein does not need 212° F. to become coagulated, as about 170° F. is sufficient, and starch does not need more than the latter temperature to disrupt the granules. Over-cooking toughens some substances, such as albumen. A great advance in cooking has been brought about by the introduction of the *fireless cooker*, which is nothing but a well-insulated casing to a receptacle which holds dishes that are boiled a short time only and the heat is retained so as to complete the operation of cooking while the temperature slowly falls. The maintenance of heat is assisted by contact with a vessel of boiling water. Heated stones or metal plates, used in such a cooker, will give temperatures that effect baking, pan broiling, roasting, etc.

With the use of *steamers* for cooking, steam seems to penetrate more deeply than water alone and on condensing to water dissolves the extractives. Where boiling in water is practised it is best to plunge the meat or vegetable into actively boiling water and then merely cause to simmer. The surface protein is coagulated and acts as a seal to prevent excessive extraction of flavoring principles. As little water as possible should be used. Certain proteins of vegetables, the globulins, are rendered soluble in salt water, and, as most boiling must be done in salt water, it is very desirable to have as little water as possible present.

Baking bread, etc., is more of a chemical operation than any other cooking process. Either carbon dioxide is formed from baking-powder, which is a mixture of mild and harmless acid and bicarbonate of soda, or this gas is formed by the action of yeast on starch and maltose, as in bread-making, or else eggs are beaten up so as to enclose air, as in cake-making. Heat expands the carbon dioxide from the baking-powder or the air held by the albumen of the eggs, until the coagulation of the protein sets the product, so that the gas bubbles form a spongy consistency. If the heat drops before the protein of the cake has coagulated, the cake falls, due to the contraction of the gases, the original expansion of which had caused the cake to rise. This practically spoils the cake unless the protein has not gone far in coagulation, in which case quickly bringing up the heat may cause a fresh expansion.

Pure foods are those that are fresh, of full strength, and without substitution of any kind. The natural instinct of mankind has through ages selected a wide range of animal and vegetable products which we now know as foods, and, because of accident or specially made tests, we have found various substances to be poisonous or deleterious when taken internally. Some things are food when fresh or when properly prepared, and deleterious when stale or improperly prepared.

Many substances which have long been recognized as pure foods and are given the sanction of the law on that account are no more tolerated by many digestions than recently introduced food preparations which the authorities, administering State or national food laws, declare impure. People, however, have known them for so long that they are in a position to judge for themselves. Reference might be made to strongly pickled products or those preserved with nitre.

Foods are in general condemned if they—

(*a*) Contain any poisonous ingredient.

(*b*) Are colored or coated to conceal inferiority.

(*c*) If any important element normally present is missing in whole or in part.

(*d*) If they are improperly labelled.

(*e*) Are below standard weight.

(*f*) Are in substitution for the article claimed.

(*g*) Are stale, decayed, or decomposed.

Since the rigid enforcement of the pure-food laws began, say a dozen years ago, there has been a vast change in the quality of foods sold. At about that time formaldehyde and boric acid were prevalent in milk; now they are practically never found, but the authorities have plenty to do to see that the milk is produced properly from healthy cattle and brought in chilled condition to market. At about the time mentioned salicylic acid and sulphites were found in a good deal of the beer sold; wheat or cornstarch in cocoa; muriatic acid in vinegar; alum in bread; wood or cocoanut shells in spices. A few years later the matter of benzoic acid in catsup, agar in ice-cream, coal-tar colors of all kinds in confectionery, the bleaching of flour with nitrous oxide and glucose with sulphur dioxide and the treatment of meat with the latter were taken up. After preventing by prosecution or discouraging by an aroused public opinion hundreds of forms of gross adulterations, it might be said that now the gross adulteration of food is at an end in this country, and attention is being focused upon raising the standards of food materials.

Spoiled and decayed food, foods of low grade, wormy or full of bacteria, although genuine, are now being sought after and removed from the market. If food can be sold in sanitary stores where flies cannot pollute by their touch or curious customers cannot sample from boxes, bins, or barrels, we are soon in a fair way towards the millennium of food supply. There should be one step, however, taken to reach this desired goal of producing and supplying food, and that would be to have standard grades of cereals and, maybe, some other things sold in less expensive packages. Rolled oats, farina, rolled and toasted corn and corn grits, a prepared rice, etc., should be sold at from three or seven cents per pound instead of twelve ounces for ten to fifteen cents. People do not always realize the great value to the public of the accurate labelling of commercial foods. One can depend fairly well upon the general statements, but must not overlook some of the fine print.

Alcohol is not, properly speaking, a food, although it gives heat. It cannot build tissue nor fat; therefore, the energy it contains cannot be stored, but is given off as fast as generated. Alcohol has physiological action on the nerve-centres, which tends to drive the blood to the surface and thus radiates quickly about all the heat it contributes to the system, and is liable to leave persons, subject to exposure a little after taking it, colder than they were before. In small quantities it aids digestion, but in large quantities it retards it. According to Hutchinson, any unchanged alcohol in the system acts injuriously. Alcohol in excess delays carbohydrate decomposition, and in this way may be the cause of diabetes and by delaying protein digestion is liable to produce a gouty condition. Sometimes only a very small amount of alcohol can be oxidized without creating unfavorable effects. Fortunately, an excessive amount of alcohol gives an unmistakable warning to the individual, and it is the part of belated wisdom to follow this warning and refrain from further partaking. The amount that different people can take differs somewhat with the individuals, but those who think they can take relatively large amounts safely are probably in most cases deceived, and quantities that may be assumed as being fairly safe for daily consumption should not be taken at one time, any more than the total daily requisite or permissible amount of food should be taken at one time. From one to one and a half fluid-

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[8] "Food and Dietetics," by Robert Hutchinson.

ounces of absolute alcohol is about all that the average adult can safely assimilate in a day when taken at different times, especially after a meal or during a meal. The following are the equivalents of one fluidounce:

Brandy or whiskey ......50 per cent. alcohol	2 fluidounces or 1 liquor-glass.
Port or Sherry..........20 per cent. alcohol	5 fluidounces or 2½ wine-glasses.
Claret or Rhine wines ...10 per cent. alcohol	10 fluidounces, 5 wine-glasses or 1 tumbler.
Bottled beer ....5 per cent. alcohol	20 fluidounces or 1 pint or 2 water-glasses.

When alcoholic liquids are used as flavoring in food, it should be remembered that alcohol is volatile with heat, boiling at temperatures very much below that of water. When pure, alcohol boils at 173° F. (See Fermentation, page 241.)

CHAPTER XIV

INDIVIDUAL FOODS

Most natural foods are made up of all the important food elements in varying proportions, and so a classification is difficult. Meat foods as a class are rich in protein and fat. Cereals are rich in protein and carbohydrates, but are lacking in fat. Oils are liquid fats. Green vegetables and fruits are lacking in fat. When the relatively large amount of water they contain is allowed for, they are normal foods with reference to protein and carbohydrates. Nuts are generally rich in protein and fat but are lacking in carbohydrates. Mineral matter is an important element in food that is found in all vegetable and animal products and is obtained in greater variety by the use of many kinds of food rather than a very restricted diet, and we must be on our guard that would-be refinements in selecting food do not reduce the mineral portion of the diet, or we would suffer as plants do that fail to find sufficient variety and quantity of mineral salts.

In food value oysters are on a par with milk, as both have about twelve per cent. total solids, but there is more protein and less fat and carbohydrates in oysters than in milk. There has been some danger in eating oysters that have been fattened in fresh water at the mouths of rivers where pollution from sewage has taken place, but the food authorities have been watchful in this matter, and there seems to be little danger at present. Many people demand salt oysters, to be on the safe side. Oysters act like the extractives of meat in stimulating digestion, and when eaten raw may impart some benefit from their natural enzymes, as some other uncooked foods do, such as apples and pineapples. Oysters get more food in the early spring from the diatoms upon which they live, and are consequently fatter and better than in the winter. *Clams* are considered as bearing the same treatment as oysters, except that there have been no cases of contamination because of fattening in fresh water, as this procedure is not practised with clams.

Lobsters, crabs, and other shell-fish are likely to be indigestible, due probably to the rather long and coarse fibres of their flesh. They are of no economic interest as food, due to their cost, and if eaten should be masticated very thoroughly. They are fairly concentrated nitrogenous foods.

Fish is a broad classification and would have to be subdivided to be treated thoroughly. The most digestible fish are those in which the meat fibres are the shortest and the flesh is freest from fat or oil. Broiled or baked fish are, generally speaking, good nitrogenous foods and are believed to be less apt to form uric acid than red meat. Due to its smaller amount of extractives, fish is not as stimulating as meat, but is otherwise nearly as nourishing. Canned fish, such as salmon and tuna, is a valuable article of diet, but should at any time be discarded if there is the least evidence of spoiling.

Eggs are so well known that very little need be said about them. They have everything needed to make bone and flesh, as they develop by heat and air alone to form the young chicken. They are too concentrated to be taken as the sole element of diet, as the system requires waste.

The nutrients of the egg are as follows:

	Water	Proteid	Fat	Ash
White	85.7	12.6	0.25	0.59
Yolk	50.9	16.2	31.75	1.09

The protein of the white of egg is albumen. The proteins of the yolk are known as vitellin and nuclein, the latter containing phosphorus of organic combination. Combined with the fats of the yolk are large quantities of phosphorus-containing substances, which make eggs very valuable as food. The digestibility of the egg is enhanced by beating up with water, milk, or other liquid to break the membranes or by incipient coagulation by heat.

Milk has been treated somewhat already in reference to balanced diet. It is the most digestible and perfect food we have, especially when it is modified in some way for special requirements, when, if possible, it is better than nature provided. When milk enters the stomach it curdles, and if it goes in rapidly it may form rather dense clots. Milk consists of fat, which is very perfectly emulsified by casein combined with calcium phosphate and lactalbumin, lactose (milk sugar), and some mineral matter, in addition to that which seems to be combined with the casein. When the protein of the milk is curdled by rennin, it carries the fat with it and leaves a clear, aqueous liquid which is a solution of the lactose and some of the salts of the milk. The albumen serves the useful purpose of retarding precipitation of casein by souring, besides assisting in keeping the fat in suspension. Analyses of some different kinds of milk of most general interest are given in the following table:[1]

Source of milk	Water, per cent.	Total solids, per cent.	Protein						
			Casein	Albumen	Total protein	Fat	Carbohydrates (milk sugar)	Ash	Fuel value per lb.
Human	87.4	12.6	1.0	1.3	2.3	3.8	6.2	0.3	319
Cow	87.2	12.8	3.0	0.5	3.5	3.7	4.9	0.7	313
Ewe	80.8	19.2	5.0	1.5	6.5	6.9	4.9	0.9	503
Goat	85.7	14.3	3.2	1.1	4.3	4.8	4.4	0.8	365
Ass	89.6	10.4	0.7	1.6	2.3	1.6	6.0	0.5	222
Mare	91.5	8.5	1.2	0.1	0.1	1.2	5.7	6.3	180

A great effort is now being made to improve cow's milk in a rational way. At first the whole effort was directed towards sterilizing milk by boiling or pasteurizing by more moderate heating, but of late the efforts have been directed toward improving milk at the source.

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[1] König, "Chemie der menschlichen Nahrung- und Genussmittel."

A modern dairy is kept as clean as a human habitation. The stalls are very simple ones of galvanized iron, etc.; the floors are of cement, with gutters for drainage, which are kept flushed, and the bedding is renewed daily. In one of the most modern cow barns the writer has seen, a picture of which is shown opposite this page, the sides of the building are almost continuous panes of glass, so that the direct sunlight shines through the building. It is heated moderately in winter, so that it can be continuously ventilated. The mangers are of heavy concrete, which can be readily cleaned. An attendant at this dairy told the writer that the walls were whitewashed every day, and that the cows were sprayed in summer time, just before milking, with a wash to keep the flies at a distance. This barn was provided with several porcelain washstands so that the milkers could thoroughly clean their hands with soap before milking. Of course, the udders of the cows were cleansed as well, and, as milk comes from the cows perfectly sterile, it is not seriously contaminated when such precautions are taken. In this dairy the milk when sold is found to contain only from 4000 to 11,000 bacteria per cubic centimetre, which is a very satisfactory

PLATE XX.

Courtesy of Percival Roberts's Dairy Farm.

Model dairy farm which produces milk low in bacteria.

showing, considering that milk allows of a very rapid increase in bacteria. Frequently milking is effected with an automatic apparatus, which is essentially a vacuum pump with a chamber for the collection of the milk, connected by flexible piping with the pump.

Milk must be rapidly cooled and kept cold in transit. Milk used to teem with bacteria, but with sanitary conditions these are now kept at a minimum. Limits for bacteria in city milk may now be set at about 25,000 or 50,000 per cubic centimetre, instead of 500,000 or 1,000,000, which a little while ago was considered about as good as could be expected for milk delivered in warm weather.

Many of the States now condemn cattle that are found to be tuberculous, and very soon this will be general. Milk is such a prime medium for the growth of bacteria that it has been the cause of the spread of much disease, particularly typhoid, diphtheria, and tuberculosis, according to the medical authorities. Everybody should know that he is getting milk from a sanitary dairy to avoid disease. There has been considerable discussion as to whether the pasteurizing of milk improved it or was a detriment. According to researches made by the Department of Agriculture in Washington, if the pasteurization is carefully effected,—in other words, carried out at a relatively narrow range of temperature,—the milk does not seem to be injuriously affected; albumen, for instance, is not precipitated.

A few words might be said of the chemistry of modified milks. *Buttermilk* is separated from butter in churning, and it contains more or less lactic acid (and, of course, myriads of lactic bacteria), depending upon whether or not the butter was made from soured cream. More or less of the protein of the milk has been rendered soluble by auto-digestion in the milk. This and other soured milks are more quickly digested than ordinary milk, as the curdling has already taken place. It cannot form dense clots in the stomach, as may happen with sweet milk.

Koumiss is primarily mare's milk fermented by means of yeast, and, as the action of yeast on sugar results in alcohol, there is some of it present. In this country sugar and yeast are generally added to cow's milk and the fermenting started in a warm place, in bottles with patent stoppers, and then put in a cool place. The enzymes of the yeast act upon the protein and peptonize it in part, so that it is very digestible. For most purposes slightly skimmed milk is preferable to whole milk. *Kefir* is milk fermented with kefir fungi and has the qualities of koumiss to a large degree, but the gas which forms is allowed to escape, so it tastes differently and more acid is formed than in koumiss.

Analyses of several of these modified milks are given in the following table:[2]

	Protein, per cent.	Sugar, per cent.	Fat, per cent.	Salts, per cent.	Alcohol, per cent.	Lactic acid, per cent.
Koumiss	2.2	1.5	2.1	0.9	1.7	0.9
Kefir	3.1	1.6	2.0	0.8	2.1	0.8
Buttermilk	3.8	3.3	1.2	0.6	..	0.3

Butter is the fat of milk with some of the protein and other of the constituents of the milk, such as salts, present in smaller amount. Sweet butter is made from cream that is not appreciably sour or acid and has no salt added to it. Most butter has had salt added and is colored with a harmless artificial color called "butter yellow," although it may have a very nice natural yellow color in summer. Pure butters differ from one another in many ways, but particularly due to a ripening or fermentation that has been effected, in which bacteria give a certain flavor, very pleasing in well-made butters. As large dairies are run under very uniform conditions, the butter acquires some slight but characteristic flavor, due to the collection of bacteria that are "leavened" from one lot to another. This condition is, however, more true of cheese, where the bacterial flavoring is of vital importance to the industry. Butter is about the most nourishing food we have, as is shown in the table on page 186. It is also quite easily digested (for a fat), due probably to the ease with which it is emulsified. Oleomargarine is a wholesome food for those who like it. It is now usually uncolored, due to the special tax imposed on colored "oleo." Butter is preferred uncolored by many connoisseurs. The fats of oleo are of different constitution and higher melting point and it does not seem to emulsify as readily as butter. If one can digest beef fat readily, he will find no trouble with the digestion of oleomargarine, and will, in fact, have less trouble, as the fats are about midway in consistency between beef suet and butter. The writer gave *oleo* an honest trial (for professional reasons), but did not relish it.

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[2] Hutchinson, "Food and the Principles of Dietetics," third edition, p. 141.

Olive oil is the one food oil after milk fat and butter that is most sought after, and rightly so, as it is very assimilable. One can depend upon the labels of bottles to disclose the genuineness of these food oils. Some cheaper oils contain carefully refined cotton-seed or corn oils, which should be satisfactory substitutes for olive oil for the benefit of those not caring to pay for the latter. Olive oil is as concentrated a food as can be found, as fats give more heat energy than proteins or carbohydrates, as has been explained, and olive oil is nearly 100 per cent. fat.

Cheese is a very valuable and cheap food when pure, and is made up of about equal parts of butter fat or fat from some other milk, protein of this milk, water, and about four per cent. of mineral matter. It is a very concentrated food. On this account it would seem more fitting to serve it at luncheon than as a course at a full dinner, after people have probably already eaten heartily, unless it be a variety of highly-flavored cheese for the purpose of stimulation and for its digestive effect.

Analysis of Cheeses.

	Water	Fat	Protein	Ash	Ratio of soluble to total nitrogen
American Cheddar	36.1	34.4	24.4	3.6	...
English Cheddar	35.2	30.4	27.8	3.4	...
Petit Suisse	54.6	35.0	7.3	0.6	3.2
Camembert	53.8	22.0	17.1	4.4	86.1
Brie	53.5	22.5	18.0	4.0	58.1
Demi-Sel	49.6	34.0	11.8	3.0	12.2
Hollande	42.6	20.0	23.9	5.5	22.3
Gorgonzola	41.5	29.0	19.7	4.8	27.2
Roquefort	36.9	29.5	20.5	7.0	47.5
Parmesan	34.0	23.0	35.0	5.2	21.7

In these analyses plain English and American cheeses show up very well in protein and fat. These were doubtless made from whole milk, as skimmed-milk cheese would not be as rich in fat. These cheeses, which have gone through certain fermentative changes, notably Camembert, Brie, and Roquefort, show a very high ratio of soluble nitrogen to total nitrogen or protein. This would tend to make them more digestible. But cheeses of this character are so distinctive in flavor that they would serve the purpose of stimulating the flow of digestive enzymes more than any other purpose and their food value would be secondary. Their cost is so high, in this country, at least, that they would not rank high as foods from an economic stand-point. Plain country cheese (low in fat) is often found indigestible, due to its density, and must be masticated thoroughly.

Meat is the muscle of some part of the animal. The muscles consist of bundles of microscopic tubes bound together with connective tissue, called collagen, and this includes more or less fat. The walls of these tubes are composed of elastin, and the contents of the tubes, when the animal is alive or has just been killed, consist of a syrupy liquid, which is like the fibrin of the blood, in that it hardens or clots. When the animal dies, this material clots, and this causes what is known as *rigor mortis,* and meat is not really fit to eat until by the action of enzymes this clot has softened, which takes some time, depending upon the temperature. When a chicken, for instance, is killed, it is generally kept in a cool place for three or four days "to get tender." This syrupy liquid in the tubes is composed of water, proteins, meat extractives, and mineral matter. According to J. König, pure muscle, freed from visible fat, has the following composition:

Protein	18.36	Extractives	1.90
Gelatin	1.64	Ash	1.30
Fat	0.90	Water	75.90

When *carving* at the table, meat should be cut across the grain in as thin slices as possible; not to give people slim helpings, but to cut the microscopic tubes into many sections so the gastric juice can attack them with as much exposed surface as possible. The tubes swell up in the stomach, the connective tissue gives way on being dissolved, and the fibres are digested. If the fibres are long and have not been cut into slices in carving, they will take longer to dissolve. The younger the meat, the more tender it is, but veal seems to be an exception, and the reason probably is that the fibre bundles are so loosely held that they are torn rather than cut through, as in carving beef or mutton across the grain, and the stomach juices have to dissolve the walls of the tubes from the outside only, instead of both inside and outside at the same time. The more fat in the tissues of the meat the slower is its digestion. As has been said before, the flavor of the meat is due to the extractives. The red color is due to hæmoglobin, which contains iron. Meat is most digestible when lightly cooked, as it is soft and more attackable by the gastric juice.

Beef and *mutton* are probably about equally matched in digestibility, corresponding cuts being considered. Ham is very digestible when the cutting can be done in thin slices across the grain, but when one comes to the stringy ends and the loose fibres the meat had better be put through a chopper to cut the fibres. Round of beef is much improved by several passages through the mill or by pounding to break the cementing tissues.

Pork is not only somewhat indigestible, due to the fat it contains, but because of the impossibility of slicing thinly across the grain. Mastication, of course, saves work in the digestive organs.

Game meats are generally strongly flavored, due to the large amount of extractives. They seem to have this because of the violent exercise the animals take, especially while hunted prior to being killed. Their muscles break down, forming amines, and the animals die before the elimination of this waste.

Chicken and most fowls have soft flesh, which is easily digested, due to the short fibres. Analyses of the meat, from "Allen's Commercial Organic Analysis," are as follows:

Kind of meat	Water	Fat	Ash	Protein
White, maximum	75.73	0.98	1.33	23.50
White, minimum	73.30	0.17	1.17	21.84
Dark, maximum	75.94	2.99	1.49	23.13
Dark, minimum	71.75	1.38	1.13	19.77

Heart and *kidneys* are dense and nearly lacking in connective tissue, therefore have to be very well chewed to be digestible. Liver is largely nucleo-protein, with very little fat and some glycogen (starch), making it a concentrated food.

Sweetbreads are composed of cells of nucleo-protein and are accepted as being very quickly digested. This is largely due to the physical properties which seem to control the digestibility of almost all food.

Tripe is protein, with a large percentage of connective tissue, which yields gelatin on long cooking.

Brains are highly phosphorized cells, composed of lecithin, etc. According to recent authorities, brain is not well absorbed, and this highly phosphorized food is not specially adapted to the supplying of tissue to the brain as ordinarily supposed.

Horse meat is much used abroad, and some writers believe it will be a standard article of diet in this country for the poorer classes. Under government supervision there is no reason why it should not be sold, as there are hundreds of thousands of people in Europe who use it in place of beef or mutton, and some undoubtedly prefer it. The writer thinks it would make as acceptable a sausage filler as worn-out cattle.

The varieties of *sausage* are too numerous to mention here. Those which are practically as perishable as ordinary meat are:

A. Fresh pork sausage.
Liver sausage.
Smoked sausage, Bologna and Frankfurt.

B. Those that are not so perishable, as they are partially dried, are known by various names, as Cervelats, Salami, Goteburg, etc. They are spiced and treated with nitre.

Cured sausages have the nourishing properties of good meat and have a high percentage of fat in most cases. The fact is they are too fatty for many digestions, especially the pork varieties.

The putting of preservatives, bread and cereals, into sausage is very much under the ban in the United States, and is little practised. Those that are bright red, such as Bologna, are treated with nitre, which changes the normal color. Corn meal is added to some pork products for local consumption, such as *scrapple,* which is sold largely in Pennsylvania, and the analysis would vary with the amount of meal used and the fat in the pork.

Tongue is a good deal like beef in composition, but the fibres are loosely held and thin-walled, so it is easily masticated and undoubtedly easily digested.

	Water	Protein	Fat	Carbo-hydrates	Ash	Fuel value per lb.
Heart, beef	62.6	18.0	20.4	..	1.0	1160
Kidneys, beef	76.7	16.9	4.8	0.4	1.2	525
Tongue, beef	63.5	17.4	18.0	..	1.1	1085
Sweetbreads	70.9	15.4	12.1	..	1.6	795
Tripe	74.6	16.4	8.5	..	0.5	665
Liver	69.8	21.6	5.4	1.8	1.4	665
Corned beef	51.2	25.9	18.9	..	4.0	1280

VEGETABLE FOODS.

Peas, beans, and lentils are of a class of vegetable foods richest in protein when considered on a dry basis, with the exception of a very few articles that are not consumed, however, in as great quantities, such as peanuts and cocoa.

Cereals are members of the family of grasses and are cultivated for their seeds, which are the storehouses of food for the young shoots. The nutritive value of the cereals ranks quite high, and they should constitute the mainstay of our diet. They are about the most digestible of vegetable food materials, as regards their protein, and are the chief sources of starch, which is the most important carbohydrate found in nature.

The nutritive value of the proteins of the different cereals is about equal, but this is assuming that they are softened by cooking and the outer protective coatings thoroughly disrupted. The cereals are too low in fat to be perfect foods, but they are generally eaten with butter, cream, or milk, which improves their nutritive food ratio. It will be seen from the following analysis that oats are the highest in fat:

Cereal	Water	Protein	Fat	Carbohydrates	Ash	Calories per lb.
Oats, rolled	7.2	16.9	7.3	66.8	1.9	1860
Corn meal (maize)	10.2	7.3	4.1	66.7	1.2	1550
Barley meal	11.9	10.5	2.2	72.8	2.6	1640
Rye flour	12.7	7.1	0.9	78.5	0.8	1630
Buckwheat flour	14.3	6.1	1.0	77.2	1.4	1590
Rice	12.4	7.8	0.4	79.0	0.4	1630
Bran	12.5	16.4	3.5	61.6	6.0	1687
Flour (roller)	12.5	11.3	1.1	74.6	0.5	1645
Graham flour	12.5	11.3	2.2	70.3	2.0	1655
Whole wheat flour	12.1	14.2	1.9	70.6	1.2	1660
Macaroni	10.8	11.7[3]	1.6	72.9	3.0	1640
White wheat farina	9.7	11.1	1.4	77.6	0.2	1710

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[3] The author would think 12–14% as about normal protein percentage of macaroni. The table and most of the other analyses in this chapter are taken from "American Food Materials," U. S. Dept. of Agric.

Because of the high percentages of nutrients in oatmeal, it is high in fuel value. It is also higher in mineral matter than the other breakfast cereals commonly used in this country. From what has been said about oatmeal, it does not leave much room for special commendation of the other cereals. As the protein of oats does not form the strong, glutinous skin that those of wheat and rye do, it is not used for bread, but is almost exclusively used as a mush or breakfast cereal. Oats and corn, being high in fat, make good winter cereals, while wheat and rice make pleasing summer dishes. Rice is so low in protein and fat that one should always use with rice dishes those rich in these elements. The Japanese eat fish with the rice. Oatmeal is, on the other hand, such a well-proportioned food that the Scotch, particularly the working classes, are reputed practically to live upon it. Macaroni is made from flour richest in gluten. The above analyses do not show as great a difference as I think would ordinarily be indicated, and, as said in the footnote, a higher figure should be given.

The wheat grain is composed of three important parts: the endosperm or body of the wheat, the germ or vital portion, and the husk or shell. The endosperm is composed chiefly of starch, with the protein richest near the husk. The starch is nearly free from protein in the centre. The germ is at one end of the grain and is composed chiefly of protein and fat or oil. The germ is very rich in organically combined phosphorus, and any germ flours or flours containing the germ would be valuable on account of this organic phosphorus or lecithin, but the trouble has been with the oil it contains turning rancid. Some millers have extracted the oil and then crushed the germ with the endosperm, but the writer feels sure the lecithin is largely extracted with the oil. He knows, from personal experience, it is with some solvents.

When the grain is lightly crushed the germ is separated and the bran removed, while the balance of the grain is sorted by sifting and regrinding to obtain ordinary household flour and pastry flour. The latter is richer in starch and so is desirable for cakes and pastry rather than bread, for which a high gluten content is requisite. The bleaching of flour is as senseless an operation as the coloring of butter.

The important different kinds of flour used in this country are:

Pastry flour—rich in starch.

Household flour—rich in gluten.

Whole-wheat flour—more phosphates and waste.

Graham flour contains more bran (needed waste) and mineral matter than whole-wheat flour. The particles of bran in the so-called whole-wheat flour are finer, and generally part of the bran is removed.

Baking-powders are mixtures of acids or acid salts, bicarbonate of soda, and generally starch. The only proper reason for the use of starch is to keep the particles of acid away from those of the carbonate, as in the presence of even small amounts of water they would combine, with a premature evolution of carbon-dioxide gas; thus, acid + bicarbonate = carbon-dioxide gas + sodium salt of acid.

Baking-powders are of three kinds, named from the kind of acid or acid salt used. Tartrate powders have tartaric acid or acid potassium tartrate (cream of tartar); acid phosphate powders have an acid phosphate, such as those of lime and potassium; while alum powders have, as acid, principally aluminum sulphate.

(*a*) Acid potassium tartrate + bicarbonate = sodium potassium tartrate + CO_2
(*b*) Acid potassium phosphate + bicarbonate = potassium sodium phosphate + CO_2
(*c*) Aluminum sulphate + bicarbonate = aluminum hydroxide + sodium sulphate + CO_2

The alum powders have been much condemned by self-constituted authorities, but the tests conducted by the United States Referee Board have demonstrated their relative harmlessness. It may be noted that the products of all these commercial powders are laxatives, —(*a*) Rochelle salts, (*b*) alkaline phosphate, (*c*) Glauber's salt, while aluminum hydroxide seems to be inert.

Potatoes rank closer to the cereals than to peas, beans, and other vegetables, so far as composition goes, although parsnips and artichokes approach them in content of starch. The sweet potato and yam are included under the head of potatoes.

The potato has approximately the following composition:

	Water	Protein	Carbohydrate	Fat	Fibre	Ash	Fuel value per lb. Fresh	Fuel value per lb. Dry basis
White	78.3	2.2	18.0	0.1	0.4	1.0	380	1798
Sweet	72.9	1.6	22.5	0.5	1.8	0.7	468	1723
Yam	79.6	2.2	15.3	0.5	0.9	1.5	346	1700

Disregarding the water, the carbohydrates are about 83 per cent. of the dry weight in white and sweet potatoes. In the sweet potato, however, there is sugar as well as starch.

	Water	Protein	Fat	Carbohydrates	Ash	Fuel value per lb.
Peas, dried	10.8	24.1	1.1	61.5	2.5	1640
Peas, green, edible portion	78.1	4.4	0.5	16.1	0.9	400
Beans, dried	13.2	22.3	1.8	59.1	3.6	1590
Beans, string	87.3	2.2	0.4	9.4	0.7	235
Beans, lima, dried	11.1	15.9	1.8	67.1	4.1	1620
Beans, lima, green	68.5	7.1	0.7	22.0	1.7	570
Lentils	10.7	26.0	1.5	58.6	3.2	1635

According to Hutchinson, the protein of legumes is not as thoroughly consumed as the protein of meat or even cereals, yet, when they are thoroughly softened by steaming or boiling, the waste is not great or of a kind to be detrimental. We all know that green vegetables are valuable as food, not so much for the nourishment they provide as for other reasons. They generally contain cellulose or allied substances, such as pectin, which goes to waste in whole or in large part. Those vegetables that contain both cellulose and starch should be thoroughly softened by cooking, so that the digestive juice can attack the starch, in spite of the protective covering of cellulose that may be over it.

The proteins of vegetables are globulins, and are largely soluble in water, especially water that contains salt; so the effort should be made to steam them and to salt them before serving, if possible. When cooked in water and salt, as seems to be common practice, there is great loss of food value, and all steamed vegetables that the writer has tried have seemed better than boiled, unless the cooking water is made into a gravy and served with the vegetable. The reason probably lies in the retention of the globulins and the nitrogenous extractives. Where meat is part of the meal the loss is not so much felt, but with a low meat diet the loss is a great one and the lack of extractives or flavor of the vegetables is liable to impair the digestion by not stimulating the flow of the digestive enzymes. Some fresh vegetables and fruits have enzymes that seem to have digestive value. If we need the help of outside digestive juice they are certainly valuable for such use.

The salts of vegetables are somewhat different from those of meat, and our complex organisms require them as well as those of meat. Fresh vegetables are supposed to have a laxative effect, but this lies largely in the influence of the waste they contain and the water that one takes in this way.

COMPOSITION OF FRESH VEGETABLES.

	Water	Protein	Fat	Carbohydrates	Ash	Fuel value per lb.
Cauliflower	90.8	1.6	.8	6.0	.8	175
Celery	94.4	1.4	.1	3.0	1.1	85
Corn (sweet), green	81.3	2.8	1.1	14.1	.7	360
Eggplant	92.9	1.2	.3	5.1	.5	130
Greens, as purchased	82.9	3.8	.9	8.9	3.5	275
Lettuce	94.0	1.3	.4	3.3	1.0	105
Onions	87.3	1.7	.4	9.9	.7	235
Pumpkins	93.1	1.0	.1	5.2	.6	120
Rhubarb	94.4	.6	.7	3.6	.7	105
Spinach	92.4	2.1	.5	3.1	1.9	120
Squash	86.5	1.6	.6	10.4	.9	245
Tomatoes	94.4	.8	.4	3.9	.5	105
Turnips	88.9	1.4	.2	8.7	.8	195

Some vegetables, such as spinach and apples, are rich in iron, but these analyses do not show the minor percentage differences which may even be those of greatest importance as food. If a varied diet be used, it is sure to include all that man requires. The natural selection by man, as dictated by his instinct, has done more than chemistry to secure what he most needs.

Fruits in the fresh state contain, as a rule, a very large amount of water, very little protein, very little fat, and more or less sugar. It would be practically impossible to sustain life upon them in any active pursuit. They would be at best very bulky foods. Raisins, figs, dried apples, and dates, as we generally get them, seem to be nutritious foods, but this is more apparent than real, for when swollen again with water, as they would have to be for digestion, they would be as bulky as ever. Dates and figs are probably the most nourishing fruits. Green fruits contain starch, which makes them indigestible unless cooked. Green apples are wholesome when stewed, as the starch granules are ruptured. Bananas are picked green to send to northern markets, and, although they may appear ripe when they become yellow, they are nevertheless full of starch and should be cooked for persons having weak digestions. They are fairly nourishing food when eaten in this way or even raw, if they can be digested. Fruit acids of mature fruit are claimed by medical authorities to stimulate the intestines. They may also neutralize some of the alkali in the intestines and lessen the fermentation. It would seem, however, with a meal including green vegetables, that fruit is not a requisite. There are enzymes in apples, pineapples, and probably many other fruits and vegetables, that may be beneficial to digestion if they are not destroyed by cooking. The enzymes cause the change of pectin to pectose, a form of sugar; but, as boiling kills enzymes, it would seem to the writer that the formation of jelly in boiling down fruits with sugar is due largely to the action of the fruit acids upon pectin. When fruits or their juices are exposed to the air, yeasts come in contact with them and cause fermentation with the formation of alcohol.

Nuts are very concentrated foods, containing, as a rule, a great deal of fat and protein. Nuts and fruit have been claimed to form an ideal food combination when taken together, but, while they might be advantageous in certain cases, they would be too expensive for most people and should be very secondary elements of diet. Nuts are not easily digested, due to the protective influences of oil and cellulose and to the difficulty of thorough mastication. Prepared peanuts or almonds, such as peanut butter or almond paste, should be more easily digested.

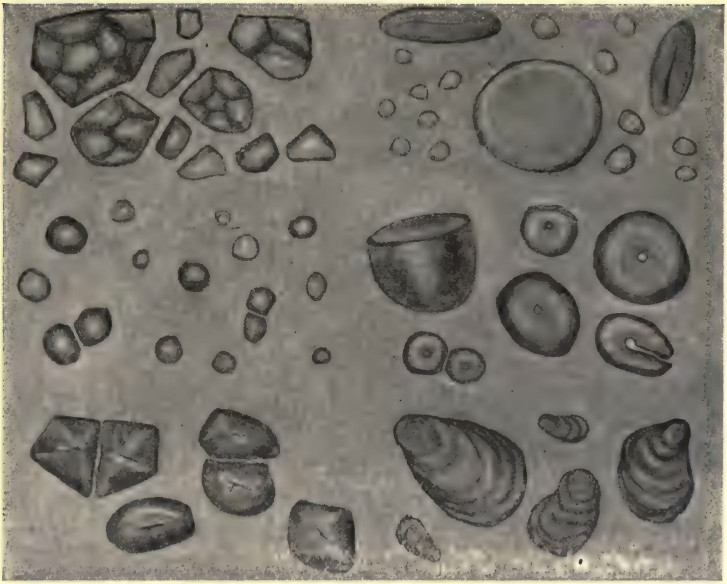
ANALYSIS OF FRUITS AND NUTS.

Edible portions	Water	Protein	Fat	Carbo-hydrates	Ash	Fuel value per lb.
Apples	82.	0.5	0.5	16.6	0.4	340
Bananas (yellow)	74.1	1.2	0.8	22.9	1.0	480
Blackberries	88.9	0.9	2.1	7.5	0.6	245
Cherries	88.6	1.1	0.8	11.4	0.6	265
Dates, dry	20.8	2.2	5.1	70.4	2.2	1370
Figs, dry	22.5	5.1	..	70.0	2.4	1395
Grapes	78.8	1.3	1.7	17.7	0.5	425
Muskmelons	89.5	0.6	..	9.3	0.6	185
Oranges	88.3	0.8	0.6	9.7	0.6	220
Peaches, canned	93.7	0.5	0.2	5.3	0.3	115
Pears	83.9	0.6	0.8	14.2	0.5	310
Pineapples	89.3	0.4	0.3	9.7	0.3	200
Prunes	80.2	0.8	..	18.5	0.5	360
Raspberries	85.8	1.0	..	12.6	0.6	255
Strawberries	90.9	1.0	0.7	6.8	0.6	175
Watermelons	92.9	0.3	0.1	6.5	0.2	130
Raisins	14.0	2.5	4.7	74.7	4.1	1635
Dried apples	36.2	1.4	3.0	57.6	1.8	1225
Dried apricots	32.4	2.9	..	63.3	1.4	1230
Chestnuts	38.5	6.9	8.0	44.9	1.7	1300
Peanuts	9.2	25.8	38.6	24.4	2.0	2560

Bread has been referred to on page 184 as a nearly complete food. Bakers' bread is fast displacing home-made bread, because it can be made cheaply and well by large establishments, which can select the most suitable flour and can and must keep everything clean and sanitary. It seems to the writer, who has thoroughly inspected some very large bakeries, that bread made in this way is the most digestible and appetizing in the long run. A large bakery makes various kinds of bread, such as milk breads, French and German Vienna, whole-wheat, rye, and Graham breads, as well as rolls of various kinds. Bakers are now beginning to wrap bread, which effects a sanitary improvement, particularly desirable for that which is handled in small shops. The writer has found bread purchased in several small shops, in the course of an investigation for the bakers, to be seriously contaminated in handling. As disease has been reduced by guarding the water, milk, and meat supplies, equal benefit should be derived by wrapping bread in a paper sufficiently pervious to allow moisture to escape, and thus keep the crust dry, but able to prevent bacteria from getting at the bread.

Cake is an indigestible combination when made with a large amount of butter, but is, on the contrary, a wholesome food, very nourishing and appetizing, if made with the minimum amount of butter. The flour contained is good food, the sugar and eggs are very

PLATE XXI.



Drawn by A. H. Sadtler.

Familiar kinds of starch. In six groups. Viewed horizontally from upper left to lower right corner: rice, wheat, cacao, tapioca, corn and potato.

Drawn by A. H. Sadtler.

Mucor mucedo. Moulds look better magnified under the microscope than on bread.

concentrated foods, and so is the butter, but the fat of the butter covers starch grains and, when cooked with them, probably penetrates them so that the digestive juices cannot easily attack either the fat or the starch. Therefore, the amount of butter used should be small, or else cake with a high butter content should be eaten sparingly.

Sugar and syrups are concentrated foods. Syrups rich in cane sugar do not seem to be as easily digested as those rich in glucose. Glucose is predigested food, —or, more exactly, starch that has been digested with acid, which is then removed,—and is ready for absorption in the intestines. Cane sugar must be first changed into glucose (dextrose) before its absorption is possible. Of course, glucose has very little sweetness, and cane sugar must be added to it to make it palatable, but pure refiners' molasses is too sweet for most people and does not keep as well as glucose syrup, unless it be concentrated, for which reason a combination syrup is much used. Maple sugar is largely cane sugar with some natural flavoring from the maple tree. There is a popular feeling that glucose is deleterious, but this is not founded upon fact, particularly since traces of impurities, such as sulphur dioxide, at one time found, have been eliminated.

With many adults, sugars and confectionery can be enjoyed at meals, or immediately following them, while if taken at other times they become sour in the mouth and cause discomfort. This is due to the ease with which they are converted into acids by bacteria, but when there is gastric juice in the stomach the sugar is protected by the germicidal effect of the hydrochloric acid of the juice and is absorbed into the blood before it sours. Sugars alone are not, as a rule, stimulating enough to cause the flow of gastric juice.

Condimental foods and sauces are only beneficial by stimulating the digestion of other foods. Some of the constituents of spices, such as cinnamic aldehyde of cinnamon and eugenol of cloves, are strong antiseptics, and probably have about the same effect on the system as other chemical preservatives. They are probably harmless in small quantities and make food more appetizing.

Tea and coffee contain a moderately active drug principle, caffeine, besides oils and tannins. Caffeine seems to act sometimes as a nerve excitant, but, according to medical authorities, more generally as a mild cerebral stimulant. Tea and coffee probably aid digestion because of the temperature of the liquid.

Cocoa and chocolate rank high as foods, as well as being mild stimulants. The fat in cocoa is quite digestible. Cocoa is unsweetened chocolate, or the content of the cocoa nibs from which about half of the natural fat (cocoa butter) has been expressed. So-called Dutch cocoa has had potassium carbonate added to make it more soluble. Chocolate is the same product containing all the natural fat and to which sugar, vanilla, and sometimes spices have been added. Their composition is as follows:

	Water	Protein	Fat	Carbohydrate	Ash	Fuel value per lb.
Chocolate (unsweetened) ...	10.3	12.5	47.1	26.8	3.3	2720
Cocoa	4.6	21.6	28.9	37.7	7.2	2320

Analyses of raw and roasted coffees are here given from Allen's "Commercial Organic Analysis":

	Moisture	Nitrogenous matter	Caffeine	Fat	Sugar	Dextrin
Raw	10.7	12.6	1.1	11.8	7.6	0.9
Roasted ..	2.4	14.1	1.2	13.9	1.3	1.3

	Tannin, etc.	Nitrogen-free substance	Crude fibre	Ash	Total aqueous extract
Raw	9.0	20.3	24.0	3.0	30.8
Roasted	4.6	39.9	18.1	4.7	28.7

Coffee extracts are coming on the market, and their use will be prevalent for those wishing to save time in making coffee and for campers, etc. They should consist of nothing but carefully evaporated coffee infusion. This process is a triumph in manufacturing that only those who have tried to evaporate coffee infusion without losing the aroma can appreciate. The extract consists of natural sugar-like solids and flavoring oils.

CHAPTER XV

ANIMAL FEEDING

The feeding of domestic animals is very much like that of human beings, as animals require certain proportions of protein, carbohydrates, and fat for the best results. The difference is largely that we must feed animals efficiently because we have only a small margin of profit between what we expend on keeping them and what we derive from them in work or food material. This matter of feeding used to be done by rule-of-thumb, but now in large stables, dairies and even chicken farms it is carried on by formula.

Foodstuffs are sold on analysis, and a table of such analyses is given herewith.

The choice of feeding rations is partly based on the dollars-and-cents cost of the protein and fat when calculated to the dry basis, but this is only the arithmetic of the matter; the science depends upon matters harder to determine. The United States Department of Agriculture has discussed the matter in a scientific and practical way in Farmers' Bulletin No. 346, and the writer refers those specially interested in the feeding of animals to this and similar publications. Only an idea of the subject can be given here.

AVERAGE COMPOSITION OF FEEEDING STUFFS.[1]

Feeding stuff	Water	Ash	Crude protein	Carbohydrates		Fat (ether extract)
				Crude fibre	Nitrogen-free extract	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Green fodder and silage:						
Alfalfa	71.8	2.7	4.8	7.4	12.3	1.0
Clover—crimson	80.9	1.7	3.1	5.2	8.4	.7
Clover—red	70.8	2.1	4.4	8.1	13.5	1.1
Corn fodder	79.3	1.2	1.8	5.0	12.2	.5
Corn silage	74.4	1.5	2.2	5.8	15.0	1.1
Hungarian grass	71.1	1.7	3.1	9.2	14.2	.7
Rape	85.7	2.0	2.4	2.2	7.1	.6
Rye fodder	76.6	1.8	2.6	11.6	6.8	.6
Timothy	61.6	2.1	3.1	11.8	20.2	1.2
Hay and dry coarse fodders:						
Alfalfa hay	8.4	7.4	14.3	25.0	42.7	2.2
Clover hay—red	15.3	6.2	12.3	24.8	38.1	3.3
Corn forage, field cured	42.2	2.7	4.5	14.3	34.7	1.6
Corn stover, field cured	40.5	3.4	3.8	19.7	31.5	1.1
Cowpea hay	10.7	7.5	16.6	20.1	42.2	2.9
Hungarian hay	7.7	6.0	7.5	27.7	49.0	2.1
Oat hay	16.0	6.1	7.4	27.2	40.6	2.7
Soy-bean hay	11.3	7.2	15.4	22.3	28.6	5.2
Timothy hay	13.2	4.4	5.9	29.0	45.0	2.5
Straws:						
Oat straw	9.2	5.1	4.0	37.0	42.4	2.3
Rye straw	7.1	3.2	3.0	38.9	46.6	1.2
Wheat straw	9.6	4.2	3.4	38.1	43.4	1.3
Roots and tubers:						
Carrots	88.6	1.0	1.1	1.3	7.6	.4
Mangel-wurzels	91.2	1.0	1.4	.8	5.4	.2
Potatoes	78.9	1.0	2.1	.6	17.3	.1
Rutabagas	88.6	1.2	1.2	1.3	7.5	.2
Turnips	90.6	.8	1.3	1.2	5.9	.2
Grains:						
Barley	10.9	2.4	12.4	2.7	69.8	1.8
Corn	10.9	1.5	10.5	2.1	69.6	5.4
Corn-and-cob-meal	15.1	1.5	8.5	6.6	64.8	3.5
Oats	11.0	3.0	11.8	9.5	59.7	5.0
Pea meal	10.5	2.6	20.2	14.4	51.1	1.2
Rye	11.6	1.9	10.6	1.7	72.5	1.7
Wheat	10.5	1.8	11.9	1.8	71.9	2.1
By-products:						
Brewers' grains—dried	8.0	3.4	24.1	13.0	44.8	6.7
Brewers' grains—wet	75.7	1.0	5.4	3.8	12.5	1.6
Buckwheat middlings	11.8	4.8	28.0	6.3	41.9	7.2
Cotton-seed meal	8.2	7.2	42.3	5.6	23.6	13.1
Distillers' grains—dried						
Principally corn	7.0	2.0	29.2	11.0	39.4	11.4
Principally rye	6.8	2.1	17.3	12.3	54.0	7.5
Gluten feed—dry	8.1	1.3	23.2	6.4	54.7	6.3
Gluten meal—Buffalo	8.2	.9	24.5	6.1	47.8	12.5
Gluten meal—Chicago	8.1	1.0	28.3	1.1	50.8	10.7
Linseed meal—old process	9.2	5.7	32.9	8.9	35.4	7.9
Linseed meal—new process	9.9	5.6	35.9	8.8	36.8	3.0
Malt sprouts	10.2	5.7	23.2	10.7	48.5	1.7
Rye bran	11.8	3.5	14.7	3.3	63.9	2.8
Sugar-beet pulp—fresh	89.9	.4	1.0	2.2	6.3	.2
Sugar-beet pulp—dried	6.4	3.3	10.8	19.8	58.4	1.3
Wheat bran	11.9	5.8	15.4	9.0	53.9	4.0
Wheat middlings	12.1	3.3	15.6	4.6	60.4	4.0

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[1] From Farmers' Bulletin No. 22, revised edition.

It is necessary to have enough of the right kind of food that is available to the animal and a certain proportion of waste to regulate the digestion and carry off the discarded material. Another point of importance is that the food should be succulent, as the fresh plant juices assist in digestion and are pleasing to the animal as favorite foods are to people.

The animal is treated as a machine, and is, in fact, an internal-combustion engine, and the food is calculated to calories or therms (1 therm = 1000 calories = the amount of heat necessary to raise 1000 kilogrammes of water (1° C.). Of course, all the fuel value in grains and grasses is not utilized by the animal, especially if the feed is dried, as usually is the case, and allowances must be made for this. Cellulose in hay, etc., is only very imperfectly digested. About fifty per cent. of the heat value of hay is utilized, and about eighty of dry grain. As fresh vegetable material is more digestible, green corn-stalks and other fresh materials such as cow-peas are packed lightly in towers called *silos,* for use when fresh pasture or fresh fodder cannot be had. Air is excluded so that the corn-stalks, etc., remain fairly fresh. There is some fermentation (because of a little air unavoidably present) at the expense of the sugars, with production of carbon-dioxide gas. This excludes oxygen, and then the alteration is arrested. There is less change in corn-stalks in forming silage than there is in forming fodder in the fields, and the food material is more fully available.

The most important element in animal foods is protein, due to its greater value in flesh forming and repairing waste in tissue, and, as the only protein of value is the digestible portion, it is treated in the accompanying table, in conjunction with the total energy value, which includes all food elements.

The requirements of animals for growth are different from maintenance. For mature animals we have two considerations in feeding:

A. Maintenance

B. Milk supply or labor.

The first requirement has been fairly well worked out for cattle, horses, etc., and for the particular animal is based on the body weight and size. It is particularly dependent upon the radiating surface of the animal, as the heat formed from the food is radiated from the surface. Coal burned in winter in heating large cowbarns is not lost, as it is a cheaper fuel than fodder silage or hay.

In addition to their maintenance animals must be fed for the work expected of them, the milk they are to produce, or gain in weight required, with steers, etc.

For milk production an amount of feed is given in addition to that required for maintenance, dependent upon the amount of milk the animal can normally give.

Dry Matter, Digestible Protein, and Energy Values Per 100 Pounds.

Feeding stuff	Total dry matter	Digestible protein	Energy value
	Pounds	Pounds	Therms
Green fodder and silage:			
Alfalfa	28.2	2.50	12.45
Clover—crimson	19.1	2.19	11.30
Clover—red	29.2	2.21	16.17
Corn fodder_green	20.7	.41	12.44
Corn silage	25.6	1.21	16.56
Hungarian grass	28.9	1.33	14.76
Rape	14.3	2.16	11.43
Rye	23.4	1.44	11.63
Timothy	38.4	1.04	19.08
Hay and dry coarse fodders:			
Alfalfa hay	91.6	6.93	34.41
Clover hay—red	84.7	5.41	34.74
Corn forage, field cured	57.8	2.13	30.53
Corn stover	59.5	1.80	26.53
Cowpea hay	89.3	8.57	42.76
Hungarian hay	92.3	3.00	44.03
Oat hay	84.0	2.59	36.97
Soy-bean hay	88.7	7.68	38.65
Timothy hay	86.8	2.05	33.56
Straws:			
Oat straw	90.8	1.09	21.21
Rye straw	92.9	.63	20.87
Wheat straw	90.4	.37	16.56
Roots and tubers:			
Carrots	11.4	.37	7.82
Mangel-wurzels	9.1	.14	4.62
Potatoes	21.1	.45	18.05
Rutabagas	11.4	.88	8.00
Turnips	9.4	.22	5.74
Grains:			
Barley	89.1	8.37	80.75
Corn	89.1	6.79	88.84
Corn-and-cob meal	84.9	4.53	72.05
Oats	89.0	8.36	66.27
Pea meal	89.5	16.77	71.75
Rye	88.4	8.12	81.72
Wheat	89.5	8.90	82.63
By-products:			
Brewers' grains—dried	92.0	19.04	60.01
Brewers' grains—wet	24.3	3.81	14.82
Buckwheat middlings	88.2	22.34	75.92
Cotton-seed meal	91.8	35.15	84.20
Distillers' grains—dried—			
Principally corn	93.0	21.93	79.23
Principally rye	93.2	10.38	60.93
Gluten feed—dry	91.9	19.95	79.32
Gluten meal—Buffalo	91.8	21.56	88.80
Gluten meal—Chicago	90.5	33.09	78.49
Linseed meal—old process	90.8	27.54	78.92
Linseed meal—new process	90.1	29.26	74.67
Malt sprouts	89.8	12.36	46.33
Rye bran	88.2	11.35	56.65
Sugar-beet pulp—fresh	10.1	.63	7.77
Sugar-beet pulp—dried	93.6	6.80	60.10
Wheat bran	88.1	10.21	48.23
Wheat middlings	84.0	12.79	77.65

About 0.05 pound of digestible protein per pound of milk is required. For horses the amount of feed is

MAINTENANCE REQUIREMENTS OF CATTLE AND HORSES, PER DAY AND HEAD.[2]

Live weight	Cattle		Horses	
	Digestible protein	Energy value	Digestible protein	Energy value
Pounds	Pounds	Therms	Pounds	Therms
150	0.15	1.70	0.30	2.00
250	0.20	2.40	0.40	2.80
500	0.30	3.80	0.60	4.40
750	0.40	4.95	0.80	5.80
1,000	0.50	6.00	1.00	7.00
1,250	0.60	7.00	1.20	8.15
1,500	0.65	7.90	1.30	9.20

based upon the amount of work required or of which the animal is capable. The following table will serve as an indication of what a horse requires for both maintenance and work, based on a body weight of 1000 pounds:

REQUIREMENTS OF THE WORKING HORSE.

	Digestible protein	Energy value.
	Pounds	Therms
For light work......	1.0	9.80
For medium work...	1.4	12.40
For heavy work ...	2.0	16.00

Having arrived at a set of figures for digestible protein and therms, it is necessary to make trial combinations on paper of the feed materials available, taking into consideration the protein and total energy or therms in each as it comes (with more or less natural moisture).

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[2] From Farmer's Bulletin No. 346, U. S. Department of Agriculture.

CHAPTER XVI

FERMENTATION

THE SUBJECT of this chapter is fermentation in a somewhat narrowed but nevertheless usual sense of alcohol formation from sugars by means of yeasts. Nothing very good is being said of alcohol in these days, and the proofs are so overwhelmingly against the general use of alcoholic beverages that it seems as if its prevalency must decline. Many industrial concerns have found that accidents happen more frequently when the workmen are addicted to the use of alcohol, and the general efficiency of the men is higher when alcohol is not used. Of course, this is regrettable, as the milder alcoholic beverages could have a proper place at the table of many people, who would not be harmed by their moderate use.

Alcoholic fermentation may be said to be the result of the ferments called yeast, acting or feeding on sugars and small amounts of mineral substances and nitrogenous matter, with the production of alcohol and carbon-dioxide gas. This variety of alcohol is known chemically as ethyl alcohol. The name might be confused with its near relative methyl alcohol, and so it is frequently called grain alcohol, because of its source.

A few words as to *sugars* may be given here, as sugar is a necessary starting-point in fermentation. Cane sugar is the sweetest of natural sugars. The formula of cane sugar is $C_{12}H_{22}O_{11}$. By taking on the elements of water (H_2O), on heating with acids, two other sugars are formed in place of cane sugar,[1]—dextrose and levulose,—which have the same formula ($C_6H_{12}O_6$), but differ nevertheless in some respects, such as rotating the plane of polarized light, dextrose, as the name signifies, rotating it to the right and levulose to the left. Levulose is sweeter than dextrose and is the chief component of honey. Dextrose is chiefly found in commercial glucose (or corn syrup), having been made by the action of strong acids on starch. The excess of acid is removed in purifying the product. Maltose is the sugar that is formed by the action of enzymes, such as diastase, on starch. It has the same chemical formula as dextrose. Milk sugar or lactose has a different formula from the other sugars and, like most of them, has very little sweetening effect. The formula is $C_{12}H_{22}O_{11} . H_2O$, or cane sugar with water of crystallization.

Yeast, a variety of fungus, is a single-celled plant and closely related to single-celled animals. In fact, it is easy to see how plant and animal life may have separated. Those organisms that acquired means of locomotion, so as better to procure their food and develop, entered the animal "kingdom," and the others remained vegetable. Yeasts grow by budding or sprouting from the parent cells. They are of various kinds, and were described by Pasteur and later more thoroughly studied by Hansen, of Copenhagen, who has classified about fifty varieties. There are only a few that are desired for fermentation with the production of alcohol in beer, ale, and wines, and these are *Saccharomyces cerevisiæ* for beer or liquors, and *Saccharomyces ellipsoideus* for wine. There are others which cause unfavorable effects or "diseases" in these products, such as *Saccharomyces Pastorianus.* So-called "brewers' yeast," or cerevisiæ, is used also as compressed yeast for bread-making. It used to be always compressed with potato starch, but can now be made free from starch, whether moist or dry. Yeasts are too small to be seen by the unaided eye, but require the use of a microscope. They generally grow so as to form a scum on the top of a fermenting liquid or a deposit at the bottom.

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[1] $C_{12}H_{22}O_{11} + H_2O = 2C_6H_{12}O_6$.

In *bread-making* yeast acts upon a small percentage of sugar, that is in all cereals, during the time the dough is kept in a warm place to rise. Carbon dioxide and alcohol are formed which are expanded by the heat. Because of the elasticity of the moist gluten and its setting in baking, bread is given the desired lightness, even though the gases finally escape by diffusion. The cut below shows the optimum temperature for yeast to be above 90° F., but it is very active at a little below 90° F., and it would seem best to keep from exceeding that temperature in the bread-mixing stage, as the favorable temperature for the production of lactic acid is being approached, with its optimum at 110° F., and lactic production must be avoided in bread-making so far as possible. The lactic bacteria are always present in the

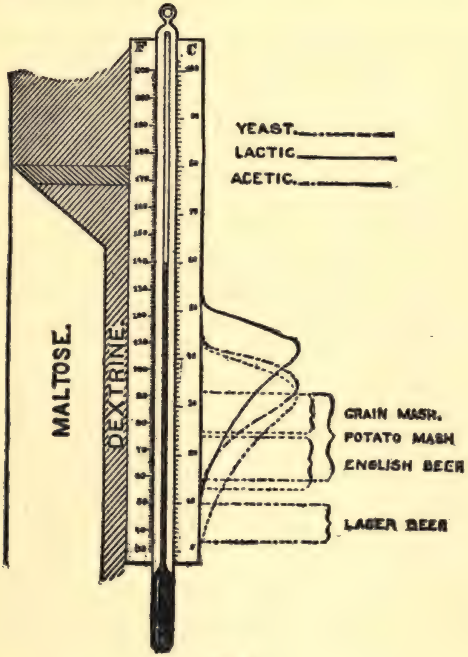

Fig. 5.

air and consequently in flour. Their growth is facilitated by a moist dough and high temperature.

Cider is fermented apple juice, but, as with all fruit juices, yeast does not have to be added, as there are myriads of yeast-cells adhering to the waxy surfaces of the fruit, and when pressed they enter the juice. Cider should be made from whole sound apples, and commercial operations for making cider and vinegar therefrom are watched by the authorities, who can detect the use of spoiled products by analyses of the finished articles. Cider is chiefly produced to make *vinegar.*

The first step in the making of cider is the ordinary fermentation with yeast and proceeds without access of air. The yeast plant does not thrive well itself without air, but it produces alcohol, it is said, better with air exclusion. The alcohol fermentation must be below its optimum temperature considerably and should be about 50° F. or a trifle less. It is best conducted in cellars, so that souring cannot take place. Acid hinders the alcoholic fermentation, which should proceed until there is about 12 per cent. of alcohol present. Of course, there must be plenty of sugar in the fruit or there cannot be a full production of alcohol. After the alcoholic fermentation the liquid is run over beech-wood chips with free access of air and at ordinary temperatures so that acid-forming bacteria and air can enter. The complete fermentation takes a year or two, but the acetification takes place in from a few weeks to as many months, depending upon whether or not the liquid is agitated or caused to flow over wood shavings, as in manufacturing establishments. The final change from alcohol to acid is one of oxidation.

$$\underset{\text{Dextrose}}{C_6H_{12}O_6} + \text{yeast} = \underset{\text{Alcohol}}{C_2H_5OH} + 2CO_2$$

$$\underset{\text{Alcohol}}{C_2H_5OH} + O_2 = \underset{\text{Acetic acid}}{CH_4CO_2} + H_2O$$

Besides using cider for vinegar-making, a fermented mash of malt is used. Malt alone makes an alcoholic liquid for malt vinegar. Cereal "grits" with malt are used, however, for ordinary distilled vinegar, after distilling the alcoholic liquid from the fermentation and acetifying.

A choice vinegar is as fine an article as a choice wine. The slow process of manufacture forms fruit ethers, which give bouquet to vinegar as they do to wines. A good vinegar should have 5 per cent. acetic acid and be well aged. If it is colorless it is distilled vinegar, which is used largely for making pickles, etc., and is perfectly wholesome for such a purpose.

Beer is made by moderately cooking in large copper kettles starchy liquids composed of malt, generally with unmalted grain added to the malt. Hops are added, and then, after quickly cooling, yeast is introduced, and the liquid fermented in wooden vats. Malt supplies the enzyme, *diastase,* to convert starch of the malt and other added starch into sugar for fermentation, and another enzyme in the malt, called *peptase,* changes the proteins of the grain into soluble and partially digested substances called peptones. Hops give a desired flavor and act as a partial preservative. Beer contains about 4 to 5 per cent. alcohol, some malt sugar, dextrin, and protein matter of the grain. Although it contains food elements, it is more of a stimulant than a food. Dark beers generally contain more maltose and there is some caramelization of sugars. This is especially true of porters. Beer supplies sugar in a very assimilable form, and the alcohol at the strength found is undoubtedly an aid in the digestion of other food, and the carbon-dioxide gas present tends to give agitation to the stomach contents. *Porter* and *brown stouts* are much used as tonics for invalids, due to their assimilable carbohydrates and alcohol content.

Malt liquors are very valuable food beverages for those who need them. Beer is not very intoxicating, but it has its maximum unfavorable effect when taken on an empty stomach. In beer-making the yeast forms at the bottom, because the temperature is held at about 60° F. at first, and later the beer is pumped to cool cellars, which are about 40° to 45° F., where the fermentation progresses more slowly. In the case of *ales* the temperature is higher, about 70° F., and the yeast floats instead of sinking, as in beer.

Malt extracts are very much like beer except that they have carbohydrates which have not been converted into alcohol and have little, if any, hops.

Grape juice contains a great deal of sugar, which is largely dextrose or grape sugar, but there are also variable percentages of levulose and cane sugar present which give the noticeable sweetness which dextrose alone does not have. There is from 15 to 30 per cent. of sugar and minor percentages of tartaric acid, protein, and salts, especially potash salts of tartaric acid, in grape juice. When fermented or changed into wine, much of this sugar becomes alcohol, and cane sugar is added to increase the alcohol content by fermentation in so-called fortified wines. *Wines* have no real food value unless they are sweet, in which case sugar is added, but they have genuine value in many cases, as in the case of beer, by aiding in the assimilation of other food, of course when taken in moderation. Wines are always fermented at relatively low temperatures, such as in cellars, so as to avoid souring. White wines are those from which the skins of the grapes are separated before fermentation. Red wines have been fermented in the presence of the skins.

Effervescing wines are fermented like other wines, but when bottled, sugar and yeast are added, which makes a second fermentation. After this has progressed, with the necks of the bottles down to prevent leakage of gas, the corks are dexterously drawn—just enough to eject the yeast sediment—and then replaced. This is done to clarify the product. Wine is not so highly prized when first made, but after a year or so flavoring ethers form by the interaction of alcohol and organic acids, such as acetic, which give the so-called *bouquet* or seeming fragrance.

Claret is a natural red wine from the Bordeaux district in France. The sugar is practically all changed into alcohol. The best-known brands are Medoc and and Chateau Margaux. A white *sauterne* is also produced in this and neighboring districts in France. Sauternes are generally sweeter than Rhine wines. *Burgundy* is a wine with more body than a claret and a little more sugar. It is generally red, but in the case of *Chablis* it is white. *Chambertin* is the best-known red variety. Hock or Rhine wine is German white wine with very little sugar.

The best-known Hungarian wine is *Tokay,* which is so low in alcohol that it does not keep well. It is very sweet, being made from over-ripe grapes, in which case the sugar is at the maximum.

The table gives weights of different ingredients in 100 c.c.

ANALYSIS OF IMPORTED WINES[2]

Wine	Grams absolute alcohol	Free fixed acid	Free volatile acid	Total acid	Sugar	Dry residue	Ash	Total alcohol in ethers
Hock (three samples)	9.73	0.399	0.088	0.506	0.062	1.92	0.17	0.042
Claret (three samples)	9.68	0.390	0.167	0.599	0.243	2.124	0.21	0.038
Hungarian wine (three samples) . . .	10.16	0.454	0.192	0.694	0.077	1.906	0.18	0.046
Greek wine (three samples) . . .	12.35	0.342	0.215	0.611	0.225	2.507	0.30	0.048
Sherry (three samples)	17.80	0.286	0.161	0.487	3.015	5.06	0.50	0.061
Madeira (two samples)	17.82	0.373	0.247	0.680	1.85	4.44	0.37	0.096
Port (three samples) .	18.11	0.309	0.09	0.434	2.54	5.34	0.23	0.053
Marsala (two samples)	16.8	0.206	0.12	0.361	3.50	5.36	0.26	0.049

Sherry is a well-known and valuable wine from Spain. It is fortified by the addition of alcohol and has had a little plaster added. It develops its pleasant flavor only on keeping. Amontillado and Oloroso are typical and standard brands. If one does not secure a known brand he is unlikely to get a genuine, mature, and well-flavored product, and imitation sherry is nearly valueless. *Port* has more body than sherry, is fortified with alcohol, and has had sugar added. Old port is very fine, but immature port lacks flavor and is too sweet for many people. On keeping, the added cane sugar seems to be inverted and is not then so sweet and is more digestible in the altered form. *Champagne* is a fortified wine produced in the province of Champagne, France. It is fermented in the bottles in addition to the primary fermentation.

We come now to the strong alcoholic drinks. Malt beverages contain 4 to 5 per cent. alcohol; wines, 10 to 20 per cent.; and ardent spirits—whiskey, brandy, gin, and rum—contain from 40 to 55 per cent. of alcohol, or by proof degrees twice these figures, or 80° to 110° proof. There are countless liquors and cordials that are produced from flavoring principles and alcohol and sugar, such as benedictine, absinthe, Curaçoa, Chartreuse. The ardent spirits are made by fermenting grain, grapes, molasses, etc., with yeasts found most suitable, and distilling the alcohol produced until the alcoholic content is right for the liquor in question, and impurities are eliminated. *Whiskey* is made from corn or rye, sometimes wheat. Corn whiskey is made either by a sour mash process or sweet mash. The sour mash produces more flavor, due to the ethers coming from the acids produced. Blended whiskeys are in many cases best for invalids, if the blend is an honest one. This is due to the fact that they are made largely from pure alcohol and thus comparatively free from fusel oil. Some well-known brands the writer has found to be almost entirely free from fusel oil. The best whiskey for tonic purposes is as near a pure dilute alcohol as can be found, with enough flavor to be pleasing. Whiskeys do not lose fusel oil on keeping, although they become more pleasant, due probably to ether formation. There have been frequent statements made that wood alcohol was present as an impurity or diluent of ordinary whiskey. The writer has never seen this substantiated, and all cheap suspected whiskeys brought to him have been found free of wood alcohol. Their rankness has been due to fusel oil, although fusel oil now is worth more than alcohol and it is unlikely at present to be in cheap or any other whiskey in quantity if the distiller can remove it by fractional distillation.

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[2] Hutchinson, "Food and Dietetics."

Scotch whiskey is made from rye, in stills over free fires, and, as the malt is impregnated by peat smoke, the empyreumatic flavor of the final distillate is imparted. *Pure alcohol* is made in many cases by the same distillers who make whiskey. The alcohol is part of the condensed distillate which is purest, and even then it is treated chemically and re-distilled to make it as pure as possible and to increase the percentage of alcohol relative to water. The final strength is about 92 to 95 per cent. alcohol by volume. Alcohol can be made from sawdust, as cellulose can be made into sugar, which may then be fermented. *Absolute alcohol* is made by distilling dilute alcohol over lime and dehydrating substances to remove the water. *Tax-free alcohol* must be denatured or rendered unfit for drinking by the addition of crude wood alcohol and benzol, or other denaturants. A formula for a general denaturant is:

Grain alcohol	89½	per cent. by volume
Wood alcohol	10	per cent. by volume
Benzol	½	per cent. by volume

It is pretty hard to prevent some workmen from drinking anything containing alcohol, and even this denatured mixture should be guarded by manufacturing establishments. Men have been known to drink shellac mixed with alcohol, and other most surprising combinations with alcohol and even gasolene.

Brandy is a distillate from wine. The best brandies have always been made from French wines, and unless one knows of a good domestic grade it would be well to purchase the best known French cognac (brandy). Judging from their composition alone it would seem as if brandy ought to serve every medicinal purpose that whiskey would, and rather better, in fact, due to its greater freedom from matters other than alcohol, water, and flavoring ethers.

Distillates from other fermented fruit juices than grapes are known by the names of the fruits, such as apple brandy, peach brandy, etc. They should contain 40 to 50 per cent. of alcohol, and are flavored with fruit ethers. The labels must set forth the actual source in accordance with the pure-food laws.

Rum is a distillate from fermented molasses, and *gin* is a grain spirit given a special aroma by the addition of juniper berries on distillation.

Milks rich in sugar, such as mare's milk, may be fermented with compressed or special yeasts, such as kefir grains. As mare's milk is not used much in this country, except as nature intended, it is customary to add sugar to cow's milk for making mildly alcoholic beverages. *Koumiss, kefir,* and other preparations are made in this way. Koumiss contains not only alcohol, carbon dioxide, and lactic acid, but the protein is generally partially digested to albumoses or peptones. These drinks are not only stimulating like other weak alcoholic beverages, but are very rich in nutrients. They could be more used to advantage. In Philadelphia and doubtless in many other places they are made regularly by the larger milk dealers and delivered to customers.

CHAPTER XVII

CHEMISTRY OF THE BODY

WE SEE in various ways that matter and force are indestructible. A plant may have a beautiful flower which withers and in the course of nature falls to the ground. It decomposes largely into carbon dioxide and water vapor, which help to nourish new plant life. The nitrogen is converted into nitrate by bacteria of the soil, and the mineral it contains assists in forming new plant growth.

The heat of the sun causes the carbon dioxide, always in the air, to combine with water in the plant tissues to produce formaldehyde, which is induced within the plant to form sugar.[1] The sugar is changed to starch by plant ferments (enzymes) and is used to support animal life. Sooner or later all animal matter returns to its elements,—to the air or soil as food for new plant life,—and the endless chains of plant-to-plant or plant-to-animal-to-plant are perpetuated.

We have just referred to the ferment or enzyme action which occurs in the green parts of plants. This

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[1]

CO_2	$+$	H_2O	$=$	CH_2O	$+$	O_2
Carbon dioxide		Water in presence of chlorophyll		Formaldehyde		Oxygen

$6CH_2O$	$=$	$C_6H_{12}O_6$
Formaldehyde		Dextrose (sugar)

enzyme action is one of the most important classes of actions that take place in plant and animal changes. When man wants to carry on a chemical change he can resort to drastic means, such as great heat, electricity, or the use of the most powerful acids or alkalies. Not so, however, in nature. The body heat is only 98.6° Fahrenheit (38° Centigrade), and plant temperatures are generally below this. Nature, therefore, had to find some way of energizing the chemicals she used, and the wonderfully perfect system of the use of ferments or enzymes materialized.

We would have great difficulty in causing water and carbon dioxide to unite to form formaldehyde and to condense this to make sugar. Outside of animal organisms we find sugars, starch, and protein substance to be fairly stable as regards oxidation, but in our bodies they are consumed regularly to produce heat and motion.

Some of the most important enzymes in plants are those that cause the action just referred to,—namely, the change of sugar into starch or of starch into sugar, as when, by the influence of the enzyme (diastase), the starch in germinating barley is changed to a variety of sugar forming the first tissues of the new plant. In animals there are enzymes similar to those in plants and still other enzymes for different purposes. Sugar (dextrose) is changed by an enzyme in the liver to a starch (glycogen), and this in turn, when it goes into the blood, is changed by another enzyme back again to dextrose, in which form it is used in the cells to give heat. Enzyme action then probably comes into play again, and the dextrose is converted, finally, into practically the same carbon dioxide and water vapor that existed when it was taken up by the plants. The transformation is in the muscle cells and creates heat.[2]

We know that the *lean flesh* of our bodies (as with other animals) is protein. The fat is much like other animal fats. Chemists have analyzed it, but the writer will not quote the results of those investigations, as it is of no great importance here. The bones are in part inorganic and in part of organic substance. The inorganic matter is chiefly calcium (lime) phosphate. The organic matter is chondrin, which forms gelatin on boiling. In old persons the bones have too much mineral matter and too little of the chondrin. This is probably a matter of the circulation rather than excess of lime in the food. The result is brittleness in the bones of their bodies.

The outer layer of the *skin* is composed of altered protein matter (protoplasm of the cells) and is a toughened tissue as compared with ordinary proteins. The skin is designed to endure considerable mechanical

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[2] $$\underset{\textbf{Dextrose}}{C_6H_{12}O_6} + \underset{\textbf{Oxygen}}{6O_2} = \underset{\textbf{Carbon dioxide}}{6CO_2} + \underset{\textbf{Water}}{6H_2O}$$

abuse, such as abrasion, and it is a heat insulating substance. When the toughening process is carried a little further, we have the tissues of the *hair* and *nails*. These tissues are called keratin. We all know from our senses about how much heat and cold they can stand. These tissues all stand acids better than alkalies. Mild acids such as vinegar do not seem to affect the skin, hair, or nails at all, but alkalies such as ammonia or sodium hydroxide attack them, and, if concentrated, quickly dissolve the thin layers of the skin. They also swell and would, in time, dissolve the hair or nails. Mild alkalies such as borax, especially when diluted in soap, do not have much, if any, unfavorable effect.

The *perspiration* that exudes through the skin contains, besides water (which constitutes all but about twelve parts per thousand), fats, acids, and, normally, a little urea. There is a little respiration through the skin, and, though only a small amount of the exchange of oxygen for carbon dioxide takes place through the skin, this minor amount is probably very necessary for some reason, and therefore the pores should be kept open, as the solid matter of the perspiration, especially fat, condenses there.

As the *blood* is our vital fluid, which is continually remaking practically all our tissues, we should consider its composition. It is composed of water which has in solution protein material, known as fibrinogen, seroglobulin and seralbumin, and saline matter; and suspended in this solution are red and white corpuscles. The blood is normally alkaline. It seems that neutral salts which we must take in food are split into components, acid and alkaline. The acid (hydrochloric from common salt) gives the acid content to the gastric juice, and the alkaline elements go into the blood. Fibrinogen is changed into insoluble fibrin when the blood clots. Dextrose is always present in the blood to the extent of about 0.1 per cent. The red corpuscles contain an enzyme that acts like the chlorophyll of plants in causing some of the most fundamental changes in the animal organism. This enzyme contains iron and is known as *hæmoglobin.* When it takes up oxygen in the lungs it is known as oxyhæmoglobin. This oxygen is then given up in the tissues to oxidize them, creating heat and energy. The white corpuscles or leucocytes are protoplasmic cells like amœbæ and can take up and digest foreign organic impurities, such as bacteria, in the same way as amœbæ absorb foreign matter, thus purifying the blood.

A very important substance in our bodies is lecithin, a phosphorus-containing substance, which seems to be the very germ or centre of the cell activities and is especially important as a constituent of the brain and nerve centres. But, while it is so important, well-selected food ordinarily contains sufficient amounts of this substance, and it is not necessary except for invalids in very special cases to select food rich in phosphorus.

In respiration carbon dioxide is given off by the blood in the lungs. The alkaline condition of the blood enables it to carry the carbon dioxide from the spent tissues. When the blood is full of carbon dioxide it contains bicarbonate, which breaks[3] down into carbonate in the lungs and thus carbon dioxide is given off.

The importance of the alkaline condition of the blood is thus shown, and it can be seen how necessary moderate quantities of salts are in the food, as the acid radicle aids digestion in the stomach, and the alkali-forming portion is required for carrying carbon dioxide in the blood.[4]

The substance of the teeth differs from the bones in the proportion of organic matter, in the density of its structure, and in containing a more acid-resisting mineral matter, called calcium fluoride. The mouth secretions normally contain alkali, which tends to protect the teeth, and if they were kept perfectly free from adhering food remnants and bacterial deposits the teeth would not be very apt to decay. But starchy food between the teeth is apt to undergo lactic-acid fermentation, and the generation of this strong acid in direct contact with the teeth attacks the enamel (the hard outside coat) and then the softer dentine underneath is likely to decay.

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[3] $\underset{\textbf{Sodium bicarbonate}}{2NaHCO_3} = \underset{\textbf{Sodium carbonate}}{Na_2CO_3} + \underset{\textbf{Carbon dioxide}}{CO_2} + \underset{\textbf{Water}}{H_2O}$

[4] $\underset{\textbf{Salt}}{2NaCl} + \underset{\textbf{Water}}{H_2O} + \underset{\substack{\textbf{Carbon}\\\textbf{dioxide}}}{CO_2} = \underset{\substack{\textbf{Sodium}\\\textbf{carbonate}\\\textbf{(in blood)}}}{Na_2CO_3} + \underset{\substack{\textbf{Hydrochloric}\\\textbf{acid}\\\textbf{(in stomach)}}}{2HCl}$

As practically all the agencies of dental decay come from bacteria in the mouth and throat, it would seem as if a very good plan would be to disinfect the mouth, especially after cleaning the teeth preparatory to going to bed, as then the fluids of the mouth stop flowing. Bacterial activity is also greater, due to the long period of action allowed it. There are several safe disinfecting washes that are efficient and some that are inefficient. *Liquor antisepticus* and *phénol sodique* are certainly efficient and safe. Physicians and dentists are, of course, able to prescribe others that may be more agreeable and as efficacious.

In addition to treating of the chemistry of the body tissues, this chapter is designed to show the influence of chemistry upon one's health. One of the most important influences the chemist has had in relation to health is his discovery of remedial chemicals, chiefly *synthetic,* or built-up substances, and in the antiseptic preparations. Important as it may be, however, this article will not treat of remedial agents that the chemist has supplied to the physician.

The health of the individual is governed largely by considerations other than the use of drugs and chemicals. This must not be taken as underrating the physician, as he is expected to serve when natural agencies fail. Natural influences contributing to health are: *Cheerfulness, exercise, fresh air, sunlight, cleanliness, pure water,* and *pure food.* The assertion that chemistry plays a part in all these categories might be disputed. It would be generally admitted that chemistry plays some part in a consideration of the purity of water and food, for instance, but as to cheerfulness and exercise it might be asked, How can they have anything to do with chemistry? The living body is a laboratory in which an innumerable number of chemical changes are continually taking place, and, just as in a highly organized manufacturing laboratory, when orders are not given or miscarry, processes will go wrong and much damage to the products and even to the plant may result, similarly in the body, if the person is nervously excited when food should be digesting or if he is unhappy, the system transmitting orders through the nerves is impaired and sufficient blood is not sent to parts requiring it, and so the chemical reactions do not take place properly. It is impossible to make chemicals or find drugs outside of the body that will keep the body healthy or vigorous, as is the natural tendency. The digestion of food, as we have seen, is effected by ferments or enzymes produced in the system. Of these substances, ptyalin, pepsin and pancreatin are examples. Normally they are supplied in proper quantities, but when the nervous system is deranged they are not produced or distributed properly and trouble ensues.

Exercise is not ordinarily treated in chemical textbooks, but is brought in here of necessity. Consider again a chemical works. Most readers may never have seen one except from the outside, but what is here said of them will probably be credited. An important consideration is often that of agitation or stirring up a liquid during a chemical reaction. When soap is made, the fat and lye are agitated by boiling so that the two layers may soon blend and form soap. When butter is being made, the cream must be churned; the ingredients of bread must be kneaded or thoroughly mixed; vinegar is made in factories very much quicker than in the home by dripping the cider or malt extract, etc., over wood chips instead of letting it remain without agitation; similarly, the chemical reactions in the body do not work quickly enough or efficiently without agitation. The reactions not only take place better when the vessels, such as the stomach, are shaken, but waste is more perfectly eliminated. Another benefit of exercise is that it promotes better breathing.

Direct sunlight has two known effects. It is a powerful germicide, being especially fatal to organisms that are the causes of most human diseases. These organisms are known as anaërobic bacteria, because they do not require air to live. Strong light is inhibitive to their activities. If it were not for the germicidal effect of the sunlight the human race might soon be extinct, due to dangerous bacteria abounding in the open air, whence they might be carried by the breezes from places of sickness to widely separated homes and places of congregation. The chemical action of the sunlight is probably due to the ultra-violet rays and ozone formed by them, and possibly other influences not at present considered; but the active effects are certain, as will be noted by the way many colors fade in the light. This was particularly noticeable before the chemist helped the dye-color manufacturer to know the classes of colors that would best resist the action of light. Besides the germicidal effect, the sunlight is invigorating. Note the way it draws the blood to the surface and thus stimulates the circulation.

The rôle of chemistry is apparent in promoting health in other ways, such as in the matter of cleanliness. People are not nowadays likely to be well unless they are clean. Savages are not as resistant to diseases to which they are subject as enlightened people; but even if they could keep well without cleanliness they live in the open, a situation naturally conducive to health. Dirt hides and protects bacteria, which are the direct causes of most, if not all, diseases. Chemistry has aided cleanliness and the preservation of health by its contribution of ammonia, alkali, soda, borax, etc., antiseptics and synthetic remedies.

It would be very interesting for the bacteriologist to investigate the bacterial contents of the dirt container of a vacuum cleaner, used in the home or public meeting-place. The microscope will show where the worn-out particles of clothing, carpets, and shoes have gone, and how much street dirt, organic and inorganic, has come into the houses, only to be promptly removed and burned or used to fertilize the garden by shallow burial where the corn or lima beans are cultivated.

Natural water contains small amounts of salts, such as lime and magnesia. In addition to mineral matter, there are nearly always some organic materials and bacteria. People generally have to drink the local water supply, but if credible authorities question its purity, it should be boiled, or else treated water should be used, so as to avoid the bacteria. Very few bacteria in water are harmful; the only one of prominence is the typhoid bacillus, as is shown in Chapter VII. As to treated waters, there are:

1. Waters from large (or sometimes small) sand filters.
2. Water that has been boiled.
3. Ozonized water.
4. Distilled water.

5. Water treated with a little ordinary bleaching powder.

6. Water treated with ultra-violet light.

Any one of these methods of purification may be good under certain circumstances. It is very satisfactory, if it can be done, to have your own purifier, such as a distilling apparatus or an electric ozonizer.

In a previous chapter the subject of food was treated in detail. To those who are normally vigorous the composition of the food is probably of minor influence upon the health. The human being is a wonderfully efficient furnace which does not need as much fuel as is generally supplied, and the amount of certain elements can be varied and yet be efficient. The afore-mentioned, often neglected, influences are so potent as to make the food itself almost a minor consideration. One reason of this is that if other conditions are not favorable good food may become a violent poison in the system, due to nervous strain or overtaxation of the digestive organs.

Reference has been made to the service chemistry has performed in supplying antiseptic preparations for medicinal and household use. The words antiseptic and disinfectant have somewhat the same significance. Septic means putrefying, so that an antiseptic is something that opposes or prevents putrefaction, or bacterial growth. A disinfectant, strictly speaking, is something used to check the spread of a contagious disease. Antiseptic is the broader term and the one I will use in this section. The following is a list of the more frequently used antiseptics. One of the very best known, namely, mercuric chloride (corrosive sublimate), because of its very poisonous properties should be used only by advice of physicians.

Ozone
Mercuric chloride
Iodine tincture
Bromine water
Potassium permanganate
Thymol
Bleaching powder
Eucalyptol
Camphor oil
Sassafras oil
Formaldehyde (formalin)
Salicylic acid
Wintergreen oil
Benzoic acid
Phenol (carbolic acid)
Boric acid
Hydrogen dioxide
Sulphur dioxide (burning sulphur)
Alcohol
Glycerin
Copperas
Zinc chloride

Oils of sassafras and wintergreen are two of the best preservatives for commercial use, such as for starch or flour paste. Safrol is the active agent in the former and methyl salicylate in the latter. Some of these substances will be referred to elsewhere in this book. Bleaching powder is used for disinfecting outhouses and cellars, and is very efficient. It is effective in quantities as small as 1 to 2 parts per million in purifying drinking water for towns and cities. Formaldehyde is of the most general use for disinfecting rooms and clothing after sickness. There are various ways of using it. Probably the best way is to use a special lamp and vaporize tablets of para-formaldehyde by heating, which causes the liberation of formaldehyde gas. Formaldehyde is effective when sprayed with water and a little glycerin. About five ounces each of formalin and glycerin are used in a gallon of water in this way. As a mild preventive it is diluted with three volumes of water and filled into saucers, and pieces of cloth are partly immersed to act as wicks and assist in vaporization. Paraffin is burned and the heat of its combustion is used to vaporize formaldehyde.

Hydrogen peroxide, as is well known, is not only an antiseptic but so powerful an oxidizing agent that it removes diseased tissue and pus, leaving the healthy tissue ready to heal. Boric acid is most useful, as it can be put on thickly and then the wound tied up. Alcohol is not antiseptic except when concentrated, and the same is true of glycerin. Copperas is used for drains and closets. It leaves an iron stain if it dries anywhere. Zinc chloride does not leave a stain and otherwise acts about like copperas.

Very important to every community is the matter of sewage disposal. A country house can easily dispose of its sewage by simple contrivances, such as properly constructed and connected cesspools and drains. The first receptacle may be made with concrete walls and is called a septic tank. From a point well down in this tank a terra-cotta pipe is fitted which leads up along the wall to about 2½ feet to 3 feet below the surface, then over to the cesspool proper. The cesspool is built up circularly of loose stone, making a pool about eight feet in diameter and of varying depth, say eight or ten feet. The upper part of the walls is drawn in a little, and the whole is capped with large, flat stones. If this cesspool is in loose, sandy soil it may be all that is required. If the soil is clayey, however, there should be a syphon instead of a cesspool connected with the septic tank, and a branching or finger drain about 2½ feet below the surface, in the direction in which the ground slopes away, and on ground receding from the house. The entrance to this finger drain must be below the level of the drain entering from the septic tank. An architect is generally requisite for laying out an adequate system.

The chemical action is in two stages. The process in the septic tank is carried on practically with exclusion of air. An energetic fermentation takes place in which complex organic matter is broken up into simpler substances. All the waste is changed into soluble matter and harmless gases. Even paper is decomposed. This thin liquid then runs into the porous cesspool, where it is acted upon by air in the loose soil and is then harmless after the oxidation which takes place. Protein is changed into ammonia in the septic tank and it is oxidized to nitrites and nitrates in the ventilated cesspool or finger drain. Harmful bacteria are themselves killed, due to the taking away of any food for them to live upon by the decomposition processes. What is done in the case of a single house can be done for a town by extended construction and additions.

Frequently in the suburbs of large cities or in small towns there are no general means of collecting the sewage and treating it, but every house has its own way of doing it. If each house has a good cesspool construction in loose soil, where the ground is not level and the houses are not built too close, the method outlined may suffice; but the writer has in mind small suburban houses built on 25-foot lots in rows, and then, no matter how good the cesspools, the ground becomes impregnated with unpurified material. In these latter cases concrete wells should be used and cleaned regularly, or there should be communal methods of disposal.

It is very desirable that there should be a printed list of active *poisons* with their well-known antidotes in every home and in every factory. In the home it is better to exclude such poisons when there is no sickness, as there is no shelf high enough to hide them successfully. But if it is necessary to keep on hand any of the well-known poisons, then the accompanying table, or a similar one, which may easily be obtained with a more extended list, should be put on the door of the medicine closet. In factories particular stress should be laid on the antidotes for poisons (all strong chemicals are poisons) that may be encountered, such as strong acids, carbolic acid, illuminating gas, arsenic, etc.

One thing of which the writer has had ample proof is the poisonous effect of nearly all gases, except oxygen or air. A person cannot breathe anything except air safely. Even relatively small quantities of gasolene, benzol, chloroform, carbon tetrachloride, hydrogen sulphide, and coal gas will asphyxiate and poison; especially the two latter gases. Carbon monoxide is the most active poisonous constituent of coal gas. It acts as a reducing agent upon the blood in the lungs, and hydrogen sulphide seems to do the same. It is very important to get rid of any corrosive sublimate, carbolic acid, strychnine, or laudanum if they are left in a house after sickness, or at most leave only one individual dose in the bottle for a possible emergency.

TABLE OF POISONS AND THEIR ANTIDOTES.[5]

Poison	Emetic or no emetic	First-aid antidotes
Hydrochloric sulphuric, nitric, and oxalic acids	Give no emetic	Magnesia, four ounces to one pint of water; or soap and water; or chalk or whiting and water to drink.
Ammonia; potassium and sodium hydroxides	Give no emetic	Lemon juice or weak vinegar to drink.
Corrosive sublimate	Give no emetic	Raw eggs beaten up; flour and water or milk.

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[5] Largely from Funk and Wagnalls's Encyclopedia.

Poison	Emetic or no emetic	First-aid antidotes
Phosphorus	Give emetic	Magnesia or chalk in milk.
Asphyxiating gases	Give no emetic	Fresh air; water dashed on head and chest; artificial respiration.
Opium, laudanum, morphine, chloral	Give emetic	Give hot coffee; keep patient awake.
Belladona and henbane	Give emetic	Give hot coffee and charcoal powder and water.
Strychnine	Give emetic	Give 20 grains of tannin in water; use artificial respiration.
Prussic acid and cyanide of potash	If possible give emetic	Stimulate with ammonia and brandy; dash cold water on head and chest; employ artificial respiration.
Carbolic acid	Empty stomach very gently	Quick administration of alcohol. Give magnesia mixed with olive oil; give raw eggs and milk.
Aconite	Give emetic	Stimulate with brandy and water, apply warmth to extremities, and employ artificial respiration.
Lunar caustic (nitrate of silver)	No emetic necessary	Common salt is most effective
Alcohol	Give emetic	Rouse the patient; give hot coffee, ammonium carbonate, and apply warmth to the extremities; employ artificial respiration if necessary.

CHAPTER XVIII

SOAPS, SOLVENTS, AND PAINTS

The term "soap" in chemistry applies to a large range of substances which are compounds of metal oxides with fatty acids. We have here to do only with the alkali soaps, such as soda or potash soaps. These are effective for cleaning by their property of forming emulsions with grease or oil, which substances seem to be the great dirt fasteners. Soap is the great dirt unfastener. The fatty acids are derived from oils called glycerides, because they contain glycerin as an integral part, just as salt contains chlorine and water contains oxygen chemically combined. When boiled with sodium hydroxide (lye) the glycerin is split off from the fat, because it has less chemical affinity for the fatty acid than has the sodium hydroxide; consequently, soap and glycerin are formed.

$$(\overset{\text{Stearin}}{(C_{18}H_{35}O_2)C_3H_5} + \overset{\substack{\text{Sodium}\\\text{hydroxide}}}{3NaOH} = \overset{\text{Stearin soap}}{C_{18}H_{35}O\,.\,O\,Na} + \overset{\text{Glycerin}}{C_3H_5(OH)_3})$$

Soap was probably first made from wood ashes thousands of years ago. Wood ashes are rich in potassium carbonate (potash), and, on boiling a liquor of this with lime, caustic potash lye was formed which made soft soap. To what extent hard soap was made from this by boiling with salt is not known to the writer, but such a practice probably dates back some time. Such a transposition or chemical reaction expressed partly in words would be

$$\text{Potash soap} + NaCl = \text{soda soap} + KCl \text{ (potassium chloride)}$$

Soaps are called "hard" if made from soda lye, and "soft" if made from potash lye. We are mostly concerned with hard soaps, as soft soaps are chiefly used in textile work and not in the household.

For the last sixty or more years soaps have been made from sodium hydroxide produced in chemical works. The earliest process for making sodium hydroxide in a manufacturing way was the "Le Blanc process," then came the "ammonia-soda" process, and now the sodium hydroxide is very largely made by electrolytic processes. In all the processes salt is used as the starting-point.

The oils most used for soap making in this country are tallow, cotton-seed oil, distilled grease (from garbage or tankage of the packing-houses), cocoanut and olive oils. In addition to these main soap stocks, resin is used a great deal in soaps for laundry purposes and serves a useful purpose, as we will see later on. Tallow forms a hard soap, and nearly all soaps have a great deal of tallow in the "stock," especially hard toilet soaps. Hard fats are more in demand for many purposes, especially soap making, than liquid fats or oils.

Hard fats contain more hydrogen than liquid fats, and it has been found that hydrogen gas can be efficiently combined with liquid fats in the presence of finely divided nickel as a catalytic agent. Liquid cottonseed oil can be changed into a solid fat like tallow by this means. The chemistry of the process is in the reaction of olein with hydrogen to make stearin, and, as olein has a high molecular weight, 884.8, and as it takes only 3 molecules of hydrogen with a weight of 6, it is not a very expensive process, taking one part of hydrogen to form 148 parts of stearin. This valuable process is the discovery of the French chemists Sabatier and Senderens. Cotton-seed oil is used a great deal with other oils. It does not form as stiff a soap as tallow and does not keep well in a soap by itself, but it renders tallow soap more soluble and is, generally speaking, a good soap stock. Distilled recovered grease makes very good soap, and because it comes from garbage is no detriment. It is used in the best soaps. Cocoanut oil makes saponification proceed more readily when it is present, and a large percentage of it makes a soap that can be used with salty water without curdling. Such soap is often called "marine" soap. It also lathers well in ordinary water, and is used in shaving soaps. Olive oil forms a good soap which is much prized by some people under the name of "Castile" soap.

There are several ways of making soap, but there is only one of ordinary commercial importance, and that is to saponify the fat with soda lye of appropriate strength while the contents of the kettle are boiled vigorously. When the "stock" is all "cut," the boiling ceases and the soap is salted out so as to separate the soap from the excess of the alkali. Water is added and a little lye, which dissolves the separated curd, and the whole is boiled longer to complete the process, and salt is again added and the spent lye run off a second time. A good deal of color is carried off each time in the spent lye. The soap-maker learns to know how long to conduct each operation by the appearance, and there is a chance for the display of nice judgment.

When the soap has stood in the kettle, say overnight, so as to allow impurities to settle out, it is run into cooling frames, and if castile soap is being made it is simply cut into bars, but if hard, dry, oval cakes of toilet soap are to be made, it is cut into chips, dried in a blowing oven, and mixed with color and perfume, and then squeezed through a narrow orifice in a machine called a "pug mill," by means of a screw, and automatically cut into cakes and pressed. This should be the purest kind of soap, as it contains hardly any water, say 5 per cent., and wears better than soft wet soaps.

People often, however, like soap to float, and that is the easiest kind of soap to make, as it is run into a machine called a "crutcher" when cool enough, and air is pumped in, which remains in it as very fine bubbles and gives buoyancy. This soap has the natural water, or about 30 per cent. The dry soap makes a smaller cake for the same weight, but it is nearly all soap, while the floating soaps are largely water and air. The writer does not want to be misunderstood as holding that they are a fraud, for they may be of good value, but the old-time hard cake has desirable properties also. Transparent soaps are rendered so by the use of glycerin, alcohol, or sugar. The former is probably most used.

Laundry soaps generally contain resin, which acts like true soap and has the property of forming very stable emulsions, so that its use may be a real benefit in laundry soaps. Some of these soaps contain naphtha, which softens the grease in soiled clothes. The use of washing soda for washing purposes is a proper addition to make, to the extent of neutralizing the natural hardness of the water so that it forms good and fairly permanent suds. One or two tablespoonfuls to a tub should be enough. Borax is probably a safer alkali to use than washing soda or soda ash, which is the dry form of washing soda, but in regulated quantity soda is satisfactory.

Millions of dollars have been spent in advertising soap powders, which are mixtures of soda ash and a minor amount of soap, and all the grades are more or less alike. It seems more reasonable to take the soda and the soap separately and know what you have of each substance. Add the soda to soften the water and use the soap as the detergent. This is an excellent plan for bathing. One can add a teaspoonful of soda to the tub and then the soap will not form a curd from the perspiration acids of the skin. The writer has seen a perfumed article consisting of washing soda and fragrant oil sold at the rate of a dollar for a ten-ounce bottle. It had a French name, to be sure, and an artistic label. *Scouring soaps* contain usually fine quartz or silica. The silica should be levigated so as not to scratch. Pumice is used as powder and in some soaps for severe cases of soiled hands. *Steel wool* (fine steel shavings) is a good article for cleaning. Used wet it will clean most smooth surfaces perfectly.

Solvents are only useful if you know which to use. In this country we have gained in recent years in acquiring carbon tetrachloride, denatured alcohol, and cheap pure benzol. Carbon tetrachloride is chiefly useful in the home, because it will not burn. It is not very useful for extracting greases, etc., on a large scale, because in the presence of water it gives off hydrochloric acid (HCl), which attacks metals vigorously and would soon ruin steel or copper vessels in which it was used. Carbon tetrachloride may not be obtainable on a small scale, in which case the manufacturer, who has put up a solvent containing, along with naphtha, sufficient carbon tetrachloride to prevent the mixture igniting, will win out and you will take home a handy little bottle that will do all that is expected of it. The writer buys this mixed solvent in 25-cent bottles rather than charge his memory with taking it home from the laboratory.

In general, soapy water is used for removing sugar stains from clothes. Carbon tetrachloride, benzine (gasolene), and benzol (coal tar) are effective solvents for grease. Ink stains are probably best removed by means of oxalic acid solution, which is, of course, a violent poison and should not be kept on hand.

Oils used for paints and similar coatings are technically known as drying oils. This is a misnomer, as they do not dry by loss of moisture but by oxidizing on exposure to air. On taking up oxygen they become thick and finally become solid and lose their sticky or oily feel. There are quite a number of such oils, as walnut oil, poppy-seed oil, soya-bean and Chinese-wood oil, but for most purposes only linseed oil need be considered. The first two oils mentioned are used somewhat in artists' colors, and Chinese-wood oil is used in some varnishes and oil stains after a heat treatment which toughens it. Chemists measure the drying properties of oils by their ability to absorb iodine, as iodine acts somewhat like oxygen in uniting with some substances. This iodine absorption is measured, and is called the iodine figure of the oil.

The iodine figure of linseed oil is very characteristic, and the test is always applied to linseed oil.

IODINE FIGURES OF WELL-KNOWN OILS

Beeswax	8–11	Lard	57– 63
Cocoanut oil	7– 9	Olive oil	81– 85
Butter fat	26–35	Cotton-seed oil	117–122
Oleomargarine	55	Linseed oil	175–190
Tallow	36–40		

Pure, fresh linseed oil does not oxidize very rapidly, and if it were used alone in paint it would not set fast enough, so *driers* are put in which induce quick setting, say in 12 to 24 hours. These driers contain compounds of lead or manganese and act catalytically, or induce action without being apparently changed themselves. So-called *"boiled oils"* have had the drying treatment applied to them. Boiled oil alone is used as a natural wood finish. For tops of dining-room tables, etc., it is used in repeated coats, as hot dishes do not affect it. For oaken drain-boards or wood that is often wet it serves as a good protective coating. If it can be applied hot it will penetrate farther then when used cold.

Paints are made up of linseed oil, drier, pigment, and a little turpentine as a thinner. Volumes of contradictory matter have been written upon the pigments in paint. The consensus of opinion up until recently has been that nothing but Dutch white lead should be used except as tinting. Recently tests have seemed to show that white lead with associated pigments, such as zinc oxide, levigated barytes, and sublimed white lead, makes the most durable paints. White lead alone is likely to chalk and come off on outside work. The main thing is to have pure boiled linseed oil, however. Linseed oil is used in linoleum manufacture by undergoing an oxidation first and then being compressed with powdered cork.

Turpentine is generally used as the thinner for paint, but a grade of petroleum known as painters' naphtha is also used, and has, the writer believes, decided advantages which outweigh those that turpentine possesses. Turpentine is supposed to assist in the drying of the oil as it evaporates, which may well be true, as turpentine forms ozone on evaporation, but good paint oil dries fast enough anyhow, and naphtha does not have the penetrating odor of turpentine.

Stains are generally alcohol, turpentine, or varnish stains. The two former will generally give the best results, as the varnish films are not apt to be good ones and one can choose what after-coat of varnish he prefers when simple stains are used.

Varnishes are good, bad, and indifferent. The bad ones are made from rosin with China-wood oil or a very little linseed oil. The indifferent ones are made largely of rosin with some hard resins like kauri, manilla, and copal, and boiled or thickened linseed oil. The good varnishes have little if any rosin and the proper proportion of hard resin, such as copal or dammar, to give a hard, elastic surface.

Spirit varnishes have no oil, and denatured or wood alcohol is used. Recently several men lost their lives applying shellac cut with wood alcohol to the interior of a large vat. The fumes of the wood alcohol probably acted as a specific poison and killed them. The fact is, however, that nearly any organic solvent might do this in a confined space. The writer knows from personal experience that benzol, carbon disulphide, and gasolene tend to asphyxiate when the vapors are inhaled strongly.

Radiator paints are composed of bronze powders in pyroxylin lacquer or a cheaper lacquer of rosin ester (a manufactured article of rosin and glycerin) and naphtha.

Paint and varnish removers have come into use greatly in the last ten years. Before their advent it used to be necessary to burn off old paint or use alkalies such as ammonia. These removers are composed of mixtures such as wood alcohol, benzol, and fusel oil, with paraffin in suspension. The paraffin acts as a sponge and holds the solvent in a thick layer and protects it from too rapid evaporation until it has had time to dissolve the varnish or paint film.

Floor and furniture oils may be briefly referred to. For waxed floors a preparation of beeswax and paraffin in fine suspension in turpentine is useful. This can be liquefied by warming on a radiator (not a stove or near fire flame). Another formula consists in paraffin which has been dissolved in hot mineral oil to the extent of a few per cent. and then the preparation is allowed to cool, so that the paraffin is in fine suspension, as is the case of the beeswax and paraffin mixture. Floors may be kept in good condition by a mixture of thin lubricating oil, such as light machinery (or orange or light-red mineral) oil, with ten to twenty per cent. of linseed oil. Where mops are used for oil dusting of floors a white "neutral" or "spindle" (odorless) oil is used.

CHAPTER XIX

PAPER AND TEXTILES

DISCRIMINATING people demand good paper as they do good cloth in their clothes. Valuable contributions to literature should be recorded on the most imperishable paper possible, so as to preserve them. It is also fitting that ephemeral literature made only to sell should be consumed to carbon dioxide and water rapidly, as seems to be the case, due to the prevalent use of ground wood in cheap paper.

If we consider labor as the backbone of life, we must consider paper as the nervous system or basis upon which all work, industry and recreation are regulated. We find that animals (or, more particularly, insects) have an extremely efficient means of production of paper. We have all seen hornets' nests. These are made of a paper pulp that is produced in the mouths of the hornets. According to Dr. S. C. Schmucker, these insects bite off fragments of wood from fence rails, etc., and chew it until the pulp is produced. Presumably the enzymes of the saliva act upon the ligneous binding matter and reduce the pieces to pulp.

Paper is essentially composed of a substance known by chemists as cellulose. It is secreted by the protoplasm of the plant to form rigid cell walls that when knit together will form a skeleton to support the plant. The ending *-ose* is used in chemistry to signify carbohydrates. These have been referred to repeatedly under foods. Cellulose has the same relative proportion of carbon, hydrogen, and oxygen atoms as starch, but evidently the total numbers of atoms in the molecules differ. Both are written $(C_6H_{10}O_5)_n$: "*n*" signifying a multiplier greater than unity. Starch occurs in more or less rounded or oval granules, while cellulose occurs in elongated cells that intertwine to form a rope or structural shape and are cemented together with allied substances. In woody tissue the material is lignin, and in immature plants the material is pectin or similar substance. Both lignin and pectin are related to cellulose, but are without structure, as they are used for cementing or binding the structural substance cellulose.

In early times stones and burned clay were used to record events of national importance and also religious and folk lore. We note in early Roman history that writing was done on wax with a pointed instrument called a *stylus*. Probably about this time writing on dried skins called parchment began. The Chinese and the Egyptians were the first people to use fibres. The former used fibres of the "paper-mulberry," which occur matted in a loose cloth or paper. The latter used strips cut from the stalks of the papyrus plant, which were woven or laid so that the edges overlapped and then the whole was wetted, hammered, and dried in the sun.

The first fibres used for paper that were made into a pulp, so far as seems to be recorded, were flax and rags, mostly of linen. Woolen rags could not be used, and, as wool was worn mostly in the northern countries of Europe, paper was made first in Italy and Spain, where lighter clothing was in vogue. After using rags and flax, grasses were used, especially that known as esparto. All this paper was made by pouring the pulp on a screen that was held so that the wire mesh was just under the water. After oscillating the screen to make the mass of uniform thickness, it was carefully lifted so that the water went through and left the fibres, which were removed on a felt or cloth and when dry formed a soft paper. Any one can do this at home by boiling chips of a soft, pithy wood with sodium hydroxide (soda lye) until a pulp is formed, and screening. Straw was also used. All these materials supplied cellulose, and to purify it from adhering substances the plants or rags were allowed to ferment, which tended to free the cellulose fibres. Paper was at first so crude that important documents were legally executed only upon parchment. It was not until they learned to use some kind of sizing or glue, with fillers, that the paper was reasonably strong and would take ink without its running.

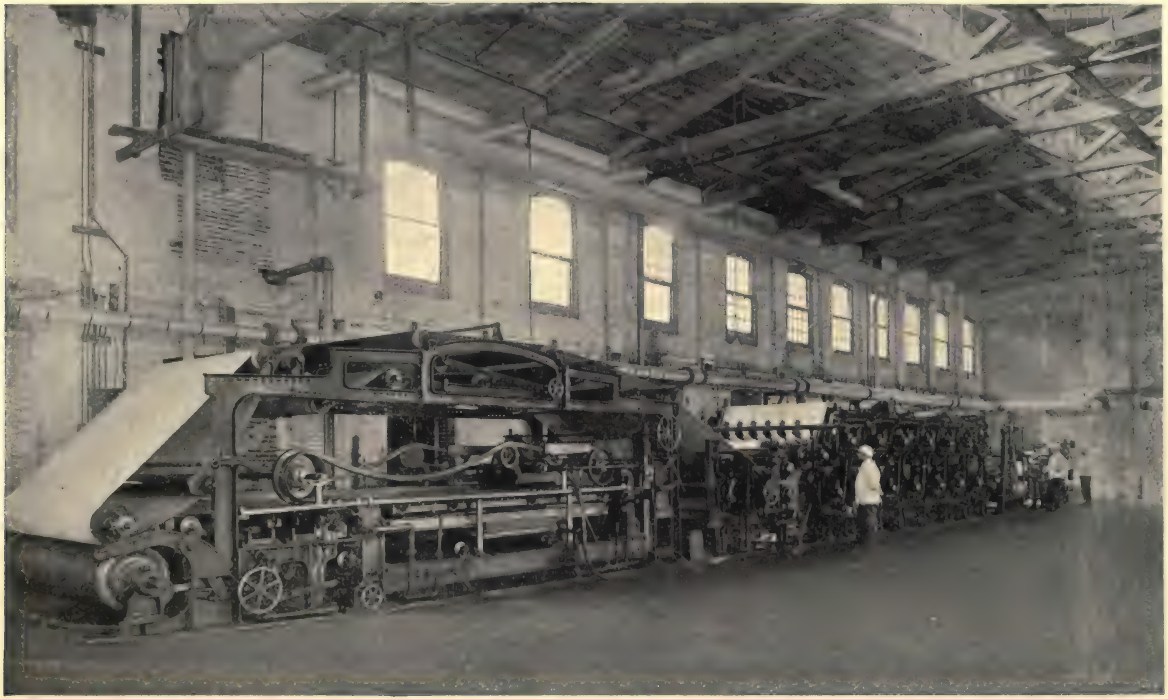
In England paper is usually made from wood pulp, while esparto, which is imported from the west coast of Africa, comes in second, and rags, used so far as the quantities collected allow of, rank third. In the United States little except wood is used for making paper pulp. Those most used are coniferous woods, such as spruce and hemlock, and poplar where the latter is obtainable. Paper does not look much like wood. It differs in color, form, and texture, but we will soon see how the transformation is effected.

The oldest process now practised for making paper uses alkali. Poplar or other non-resinous wood is used in a chipped condition. The boiling is effected in closed kettles, two or three ordinary stories in height and thoroughly insulated to retain the heat, which rises, because of the pressure employed, to about 330° to 365° F., equivalent to a pressure of 100 to 150 pounds per square inch above the atmospheric pressure. This high temperature facilitates the action of the alkali upon the lignin which binds the fibres. Nine-tenths of the sodium hydroxide used is recovered by evaporating the boiled-off liquor, burning off the organic matter, and heating with lime. When sufficiently cooked the contents of the digesters are run off, washed, and then the fibres are beaten with water until they are all loose and separate. This material is ready for paper making proper. It is sold in loose sheets called "half stuff" or "pulp," or used in the same mill to make paper. It is agitated with bleaching-powder solution to whiten and further purify it, washed, and then run upon the paper-making machine. This does the work in rather better fashion than a man used to do with a screen. Generally size, consisting of rosin, soap and alum, is put into an agitator, called a beating engine, with the pulp, where it is sent around an oval race-course with water by means of paddles or blades that revolve, nearly touching other blades forming a bed-plate. Clay and other fillers and colors are also put in at this stage. The clay and the size fill the voids in the paper and fix the colors. The paper-making machine is a long affair, with a good many parts: for making the magma of fibres like the hand screen, taking it off in felts, rolling it, drying and calendering it or "ironing" to put a gloss or finish upon it. The end where the screen is is called the *wet end,* and of course the other is called the *dry end.* The whole machine is often considerably over 100 feet long and makes paper up to 18 feet wide and in continuous length in rolls.

The other processes are similar, except the cooking or boiling. One process is "mechanical," in that the wood is ground up on rapidly revolving grindstones and is then made at once into paper. Sulphate pulp is much like soda pulp, but sulphate of soda is used to make good the loss in the process instead of sodium hydroxide or sodium carbonate. This is cheaper and it makes a paper superior for many purposes. One is very likely to hear of Kraft paper nowadays. Kraft is German for strength. This paper is "soda pulp" in which less soda is used and the intercellular lignin not fully removed, so that when made into paper it acts as a size or binder for the interlaced fibres. There is no bleach used, and the result is a brown paper of considerable strength used for wrappings. The most important process of all now is the sulphite process, although the sulphate process has made inroads into the business recently. In the sulphite process the cooking is done in tile-lined, acid-proof digesters, with a liquor made by passing the gas (sulphur dioxide) from burning sulphur or pyrites through a column of dolomitic limestone kept wet with water. By this process a pulp is produced that is easily bleached and can be used for a great variety of papers.

The *water-mark* frequently found in paper is an imprint from a design on the screen at the wet end of the press or on the first drier roll. Paper or pasteboard boxes are made from old paper by putting it through beaters, which, in the presence of water alone, break it up by the teeth or iron paddles of a revolving drum, which pass over stationary teeth called a "bed-plate." Color is generally added in the beaters and size also.

PLATE XXII.



Courtesy of the Chester Paper Company.

Foudrinier paper machine.

Several thicknesses are often united by means of silicate of soda when used for box boards.

One can make a *linen* or a *bond* writing-paper out of chemical wood pulp by the choice of pulp, the length of time it is beaten, by varying the size and the pressure of the rolls. Rags are used, generally mixed with wood pulp in the best writing-papers, but are not essential for a strong and fine-appearing paper. An expert can tell by means of a microscope what kinds of fibres are used in a paper, but the person without facilities can judge a paper only by its appearance and its resistance to folding, crumpling, and tearing. Mechanical wood pulp is easily detected by merely leaving the paper in the direct sunlight for a day or two, when it turns yellow. Art and coated papers and cards are usually sized with casein or precipitated milk curd made into a paste with alkali or borax and filled with clay. This coating puts a perfectly smooth finish on the paper when calendered, so that illustrations will show up to advantage. Practically all book papers are finished with size, and all surfaces to take lithographic impressions are heavily sized and loaded with clay.

Paper is used to make an *imitation parchment* by passing it quickly through somewhat diluted sulphuric acid, which gelatinizes the outsides of the fibres, and when the excess of acid is washed off and the paper dried it has lost its porous condition and is like parchment. It is used for wrapping butter, lard, bread, etc. Instead of sulphuric acid, zinc chloride is sometimes used, which acts a good deal the same as sulphuric acid by abstracting the elements of water from the cellulose. Layers of paper treated in this way with zinc chloride are compressed to form what are called "fibre" articles or "hard fibre." It is used for trunks, suit-cases, etc., and for electric insulation. When paper pulp is beaten a long time it swells up and in the earlier stages is used to make bond and India paper, and when it has gone practically the limit of the process for several days it may be compressed to make a non-fibrous substitute for celluloid, called "cellulith."

Celluloid itself is made from a pure white tissue-paper by nitrating with a mixture of sulphuric acid and nitric acid. This nitro-cellulose, when heated with camphor, unites to form celluloid. The transparent celluloid is the purest variety. It is colored white with zinc oxide, and other pigments are used for other opaque colors. Transparent goods are often colored with aniline dyes. Pyroxylin is moderately nitrated cellulose and is used for the finest transparent lacquers. Gun-cotton is fully nitrated cellulose. There is about 10 to 11 per cent. of nitrogen in the former and 13 per cent. in the latter. Celluloid, pyroxylin, and gun-cotton all flare up if ignited, but do not ordinarily explode in small quantities unless in a confined space.

There have been many patents taken out for processes to make celluloid non-inflammable.

Textiles is a subject allied to that of paper. If the wood fibres were long enough they might be spun into thread and woven into cloth.[1]

Cord and rope are made of *hemp* for dark grades and cotton for the white grades. Bagging is made out of *jute,* which is a first cousin to hemp and a second cousin to flax.

All the pure fibres so far referred to are made up of cellulose or a compound or mixture of cellulose and lignin or similar substances and do not contain nitrogen. We will further on treat of wool and silk fibres, which are entirely different from cellulose fibres and contain nitrogen. One can tell those containing nitrogen by holding the threads in the flame of a match. They shrivel up and give off ammonia fumes which change moistened red litmus blue and smell like burning hair. With this test *artificial silk* acts just like cotton, from which it is made, and not at all like true silk, which it resembles only in appearance. If one has the opportunity to examine the different textiles with the microscope, separate a few of the fibres from one of the threads, place them on a glass *slide*, wet and cover them with a fine glass disk called a *cover-glass*.

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[1] Cotton fibres are from 20 to 40 millimetres in length.
Flax fibres are from 25 to 30 millimetres in length.
Hemp fibres are from 15 to 25 millimetres in length.
Jute fibres are from 1.5 to 4.0 millimetres in length.
Esparto fibres are from 0.5 to 3.0 millimetres in length.

MICROSCOPICAL CHARACTERISTICS OF FIBRES.

Linen	Jointed fibres, round and tapering.
Cotton	Twisted bands or ribbons.
Wool	Filaments with overlapping scales.
Silk	Smooth fibres, generally in pairs, no canals.
Hairs	Straight filaments much like wool, but with smoother scales.
Artificial silk	Smooth single fibres, much like true silk in appearance.

Cotton grows as seed-hairs which are designed by nature as a means of scattering the cotton-seeds in the wind when they are ripe. It is separated mechanically from the seeds in the *ginning* machine. The seeds are pressed to furnish a valuable oil, and the residue is known as cotton-seed cake or meal, and is a valuable food for cattle. The fibres go through mechanical operations of carding (combing), spinning, and weaving. Cotton cloths, muslins, gingham, outing flannels, etc., are cooler than the same weights of wool, wash better, are stiffened with starch better, and serve altogether different purposes. Cotton goods are apt to be so heavily sized as to give them an appearance of linen or a greater fulness than they would naturally possess. This deception can be detected by making note of the number of threads per inch or their size as compared with other goods and by washing.

Cotton yarn is given a fine lustrous appearance called *mercerizing* by dipping the "hanks" in strong sodium hydroxide solution while under tension, washing, and drying. It takes dyes better than untreated cotton and has a silky lustre.

Linen is a rather finer fibre for most purposes for which cotton is suitable. It is more costly, more lustrous, stronger, and lasts longer than cotton. Linen is obtained from flax by breaking and retting (a fermentative change), by which the incrusting matter is loosened from the cellulose. Though it is essentially cellulose like cotton, the fibres are tougher, just as cotton is stronger and more durable than wood-pulp cellulose.

Wool is a fibre that is a poor conductor of heat. It has a smooth surface, so it does not collect dirt as much as cotton, when the two are woven into cloth. Some woolen fibres are very soft and fine, like Australian wools and alpaca; others are coarser and some that merge into hair are so coarse and stiff that they are suitable only for carpets. Wool takes dye colors better than cotton. In fact, there are only a few dyes that fasten themselves to cotton without the cotton having been treated with mordants such as tannin and metallic salts, while there are only a few that do not readily dye wool. Advantage of this fact is taken in testing for coal-tar colors in foods. A little piece of white *nun's veiling* is put into the food, after being thinned out with water, a few drops of acid added and brought to a boil. In a little while the woolen cloth will become highly colored if the food contains a coal-tar color, although it may take up some slight stain from vegetable colors.

BEHAVIOR OF CLOTH TO MINERAL ACIDS AND ALKALIES.

	Acid	Alkali
Wool	No effect	Dissolves if concentrated.
Silk	No effect unless concentrated and hot.	No effect unless concentrated.
Cotton	Disintegrates	No effect
Artificial silk	Disintegrates	No effect

Cloth that contains wool and cotton can be analyzed to find the percentages of both substances by moistening with dilute hydrochloric acid and then drying out completely. When the acid becomes concentrated by drying, it attacks the cotton fibres so that they fall to pieces, leaving the wool. As a good deal of this *union* cloth exists and as the wool is wanted for *shoddy,* this process, called *carbonization,* is effected and the wool is reclaimed and used in cheap clothing. These fibres of shoddy can be distinguished from untreated wool by their broken and frayed appearance, especially when seen under the lens. In choosing woolen cloth it is well, when in doubt as to quality, to pull out the fibres and select only cloth with long fibres in the filling. The warp, which is the skeleton of the goods, is harder to examine and not quite so important in the wear in most cases. Where both classes of threads (warp and filling) come equally to the surface, their quality is of equal importance. Wool does not take hot soap well or one containing any alkali, as it tends to felt the fibres and thus shrink the goods.

Silk is a good insulating fibre like wool; in fact, as it is finer it is apt to be a warmer covering. It wears well because it is both tough and smooth. Wool is apt to catch on objects because of its curl or scales and thus wear away, but silk does not catch and as a result wears very much better. Silk is not affected unfavorably by hot, soapy water.

Artificial silk is made by dissolving cotton or a compound of cotton in a suitable solvent and throwing it out of solution or combination at the same time it is forced through a fine opening, thus producing a thread. It is of the same chemical constitution as cotton. Artificial silk is made from cellulose in the form of cotton, or wood pulp. Pauly silk is a variety made by dissolving cotton in a solution of copper in ammonia and then squirting the solution through fine openings called "spinarettes" into sulphuric acid. The thread is washed thoroughly and dried under some little tension to give it the maximum degree of lustre. Chardonnet silk is made from nitrocellulose by passing a solution in alcohol-ether through spinarettes into water containing calcium sulphide, which takes away the explosive character by removing the nitro-group and leaving cellulose. Viscose silk is made by the interaction of sodium hydroxide, carbon disulphide, and cellulose, which make a xanthogenate. Cellulose is reformed by spinning into a suitable solution. Acetyl cellulose is also used for artificial silk. All these varieties of artificial silk have been used in this country to some extent and several of them are being made here. They are not so strong as true silk, especially when wet, but dye in all colors and are used in braidings, etc.

Fire-proof cotton goods have been successfully made at last, by a process devised by Dr. W. H. Perkin, of England. He uses two compounds in such a way as to produce a tin salt of a tin acid, which is rather a remarkable combination but very effective. Outing cloth is made more fire-resistant than wool in this way.

CHAPTER XX

LEATHER AND RUBBER

LEATHER and rubber are not related, but for convenience they will be included in one chapter. To understand leather we should know how it is derived, and therefore something of the nature of hides must be considered. Skins and hides are made up of two layers,—the epidermis or outer skin and the derma or true skin. The epidermis consists of cells, which form next to the derma and are pushed up to the surface, where they become flattened, and finally are worn off as scales. The epidermis extends down the hair-pits to the end of the hair-roots, and when unhairing takes place in making leather the epidermis is also removed. The derma consists of fibrous material, or coriin, which forms the leather on tanning. Fig. 6 (p. 288) shows the essential parts of a section of skin, with hair, hair-sheath, hair-erecting muscle, hair-papilla, sweat-gland, *derma* (*C*), etc. The cuticle can be seen coming down into and lining the hair-pit. When hide is fresh it is soft and pliable, and at ordinary temperatures it will putrefy unless treated in some effective manner. If fresh hide be boiled with water the collagen contained is largely converted into glue, while the associated coriin remains insoluble. In making leather all material of the true skin or hide is rendered stable under ordinary conditions, and even on boiling in water, no glue is formed.

The skins of goats and sheep are used chiefly for light leathers, and those of calves, cattle, and horses, called hides, for heavy leathers. Of the lighter grades, goatskins are preferable, as they make the beautiful, light, yet strong morocco, while sheepskins form a similar leather, but with too much stretch in it for most purposes. Calfskins are used for men's uppers when morocco is not preferred, and the thick hides of cattle are used for sole-leather. Horse-hides are often split into two layers for enamelling. It is a little surprising how the machine does it so evenly, thus making two thicknesses. Other machines measure the number of

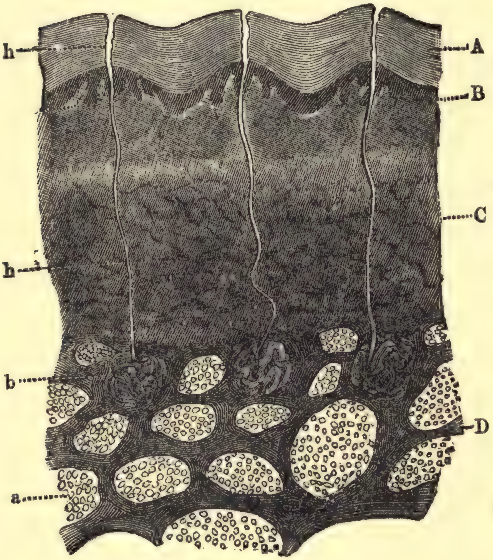

FIG. 6.—Section of hide.

square feet of an irregular skin, with "neck" and "shanks."

Until recently tannin-containing materials, such as bark, were the all-important substances for making leather, as only comparatively little leather was made by alum tawing and treating with fish oil or chamoising. Now the great and growing process is chrome tanning. This is a true chemical process and makes more water-resistant leather than bark-tanned leather. Some of the materials used for tannin extracts are oak, chestnut, and hemlock bark, sumac, myrobalans, cutch, etc. No matter what the tannage, the skins must be unhaired by soaking in lime water, and, if there be some of the old, rank lime water present for starting new baths, all the better; as bacteria help in this work, as they do in so many other operations favorable or unfavorable to man's schemes. Often the bacterial action goes too far in hot weather and spoils the skins. Ordinarily in a couple of weeks the hair will come off after this lime treatment, which is finally aided by men with knives, who easily scrape it off.

After the unhairing the skins are washed and given a bath in some kind of dog, pigeon, or other *puer* or *bate,* which swells the hides and draws out excess of lime. Latterly artificial puers have been introduced. Large hides receive a fermenting bran "drench" which supplies lactic acid for the removal of lime. After more washing it is ready for tanning with bark extract for hides and bark or chrome for light skins. Personally, the writer is more familiar with chrome tanning and will briefly describe the process. In this work the soft skins are saturated with a solution of sodium or potassium dichromate and hydrochloric acid, and after the excess is squeezed out they are put into a bath of hyposulphite of soda (the same chemical that is used as a fixative in photography). This reduces the chromate to a green compound of chromic oxide, which combines at once with the collagen, the interfibrous cement, and thus makes a dense, nearly water-proof, and permanent tissue. There is still plenty to do in making the finished article, as it has to be dyed in a soapy emulsion, called fat liquor, dried, dampened, worked with glycerin and neat's-foot oil, stored in a loft a while to set the combinations, and then dressed with gum arabic, egg albumin, etc., and "ironed" with heavy glass pieces on a special machine which holds both leather and the glass "iron."

White glove leathers are often treated with alum, which does not tan them so that they will stand water, but merely preserves them, and they are softened with something like egg yolk. This treatment leaves the leather pure white, while chrome tannage gives the leather a greenish tinge in the centre where the dyes do not penetrate. Bark-tanned leather is yellowish to yellowish-red throughout, except where it may be stained on the surface. Oak-tanned sole-leather is light in color, chestnut is medium light, but hemlock is reddish, unless it has been bleached. The oak and chestnut leathers are stronger. Bark-tanned leather does not resist water as well as chrome-tanned leather, although all leather will absorb water unless saturated with some special water-proofing substance. Neat's-foot oil tends to make the leather water-proof and is good for the leather, but for uppers, if used in excess, it prevents the shoes taking a good polish. Some water-proofing preparations seem to consist of viscose solutions.

Besides the processes mentioned there is the chamois process, which depends upon the oxidation of fish oil right in the pores of the skin.

Sometimes the grain surface is intentionally rubbed off of morocco leather, which gives the effect known as *suede leather.* *Patent leather* is made by putting a varnish surface on the rough or flesh side of leather. The varnish is made of linseed oil that has been thickened with heat and has mineral substances present, such as dioxide of manganese and Prussian blue, which hasten oxidation or drying of the oil. It also contains coloring matter, such as Prussian blue and lamp-black. If this coating is put on the grain side, it is called *enamel leather.* The leather must be degreased before being made into enamel leather or it will not take the varnish so that it will stick well. Enamel leather is less likely to crack than patent leather, as it is on the grain side, which is not as easily stretched as the flesh side, to which the patent leather surface is applied. Very little stretch must be expected of either of these treated leathers, and shoes should fit when first tried on. To preserve patent or enamel leather treat with an oil such as neat's-foot oil, with the excess rubbed off, or use a good oil-paste polish. All leather is better for a little oil. When shoes are soled they should have rubber cement between the leather layers so they will not rub and squeak if the layers become warped. When this occurrence happens the soles should be soaked a while in neat's-foot oil.

The writer has often wondered why, when he has tried on new shoes, they seem to fit, yet when they have been worn a while they pinch. It used to be supposed that it was due to lime or tannin. There should not be any lime in leather, or it would cause other troubles such as lime soaps, which bring out blotches, and it cannot be tannin in most cases, as most upper leather nowadays is chrome tanned. It would be most reasonable to ascribe it to the absorption of moisture from the foot and consequent thickening of the leather, which results in a shrinking of the opening for the foot. When leather becomes stiff it can often be improved by rubbing it first with neat's-foot oil and then glycerin. The writer doubts if leather can be rendered water-proof and yet possess pliability. In technical work it is impregnated with rubber, which protects the leather and makes it stronger. Russia leather is soft, bark-tanned leather, impregnated with oil of birch, which gives it the peculiar odor.

Rubber.

Rubber, India-rubber, or caoutchouc[1] is a very important and very interesting substance, because of its properties. Rubber was known to the natives of tropical America before the discovery of this hemisphere, and the Spaniards not only were aware of its use for balls but used the milky juice of the plants, called *latex,* for coating garments to make them water-proof. The fabrics were probably dried after being smeared with the latex, when the rubber particles united as a film. Before or at the beginning of the eighteenth century, apparently, tubes and other flexible articles were made for surgeons and chemists.[2]

Early in the nineteenth century raw rubber was cast or moulded into shoes and other articles, and it was not until 1843 when Goodyear, an American, discovered that heating raw rubber with sulphur changed its properties so that surfaces would not adhere when pressed together. This discovery greatly extended its usefulness.

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[1] Caoutchouc has the empirical formula $C_{10}H_{16}$.

[2] The writer finds this set forth in Chaptal's Chemistry, translated by Professor Woodhouse, of the University of Pennsylvania, 1807.

Rubber is obtained from plants of the *Euphorbiaceæ*, chiefly from that known as *Hevea Braziliensis.* This tree grows wild in the forests or jungles of the Amazon and the Orinoco and other tropical places, and in recent years has been grown on plantations. So far, the native article from the Amazon Valley, known as Para rubber, is the best.

All natural rubber contains resinous matter which is inelastic, but Para rubber contains the least of all, or about 3 per cent., African about 10, while Guayule rubber, which is obtained from a small plant in Mexico, contains about 40 per cent. Rubber from the Guayule is not very elastic, although it is serviceable for some purposes where toughness is chiefly requisite. The resins can be extracted by means of solvents, such as acetone, and this has apparently been done by some of the big rubber-tire companies, as the writer knows of thousands of tons of these resins being on sale where tires are made. These resins are closely related to the true rubber or caoutchouc and appear to be oxidation products of the same. Pure rubber absorbs oxygen from the air, and material is formed similar to these naturally occurring resins. Light facilitates this oxidation, so rubber tires should be kept in dark places.

The purest kind of rubber is now made synthetically. Simultaneously Professor Harries, in Germany, and Dr. F. E. Matthews, later associated with Professors Perkins and Fernbach, Sir William Ramsay, E. Halford Strange, and others, in England, succeeded in making rubber economically. In England it was at first made from acetone, and later from fusel oil. Means were also found of obtaining fusel oil quite cheaply by bacteriological action, more directly than formerly made as a by-product in the production of alcohol. Due to the increased production, rubber has become much cheaper, and it will probably never again rise to the price of three dollars a pound, as it was a few years ago.

Vulcanization of rubber is effected by heating it with sulphur or certain compounds of sulphur, such as antimony sulphide. As sulphur gases would tend to form on heating rubber with sulphur alone,[3] zinc oxide is generally added with the sulphur to absorb them by forming zinc sulphide. The temperature of vulcanization is usually about 275° F., and the operation is carried out in closed vessels, or autoclaves, called vulcanizers. This is done to prevent a porous condition of the rubber, for, even if zinc oxide is used to absorb the sulphur gas (hydrogen sulphide), water would be formed, and if it tended to escape the goods would be spongy.

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[3] $C_{10}H_{16} + S_2 = C_{10}H_{14}S + H_2S$;
$H_2S + ZnO = ZnS + H_2O$.

Some kinds of rubber goods cannot be subjected to heat, and a cold process is carried on with a liquid combination of sulphur and chlorine known as sulphur chloride. Rain-coats are treated this way, and it is necessary to have zinc oxide, magnesium oxide, or alumina (something that will absorb hydrochloric acid) present, as some of this acid is apt to be evolved, although this formation is not theoretically the result of the action, as both the sulphur and the chlorine are supposed to unite with the rubber.[4]

Vulcanized rubber or *hard rubber,* for fountain pens, insulating objects, etc., is made by using 25 to 40 per cent. of sulphur, while in ordinary processes for soft goods 2 to 3 per cent. is used. Red rubber is generally made by using antimony sulphide (Sb_2S_5). As this is not as strong as sulphur, it is necessary to use about 10 per cent.

Fillers for rubber articles, such as tires for automobiles, are composed of zinc oxide, fine clays, levigated barytes, etc. To cheapen the rubber and render it softer and more workable, to neutralize the hardening effect of the mineral fillers, and to make it less absorptive of oxygen, oils, such as petroleum oils, blown petroleum oils, tar products, etc., are incorporated. The writer has noticed that perfectly pure, unvulcanized rubber becomes brittle sooner than loaded goods. The secret of making good tires lies in removing the natural resins and adding viscid oils, such as blown petroleum, and fine neutral mineral fillers with some basic substance, such as zinc oxide.

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[4] $C_{10}H_{16} + SCl_2 = C_{10}H_{16} . SCl_2$.

A few words on the manufacture of some of the commonly used forms of rubber may be of interest. *Rubber shoes, etc.,* are made by coating cloth with a mixture of rubber, sulphur, mineral matter, and oils (for the inferior grades, reclaimed rubber also), which has been calendered to thin sheets and then hot-rolled to the cloth. Strips of this rubberized cloth are then stretched over lasts and when all formed are heated in autoclaves to the vulcanizing temperature.

Thin sheets for dental purposes, tobacco-pouches, etc., are also made by forming blocks of soft, vulcanized rubber, freezing, and then cutting with rapidly revolving saws regulated by micrometer adjustment. *Rubber thread* is made by winding thin, calendered sheets with talcum powder to separate them; the whole is tightly wound and vulcanized and then cut, according to size, transversely, as thin sheets are cut. *Tubes for tires, etc.,* are made in sheets and then cemented and vulcanized. *Automobile shoes* are made up on forms by hand wrapping layers of rubberized fabric and rubber composition and then moulded with excess of rubber composition to form the tread and vulcanized in the moulds. Sometimes they are vulcanized without the treads, and then the treads are vulcanized afterwards.

Direct sunlight and moisture act upon rubber and weaken it, and the only protection is to keep the goods or tires in as dark and dry a place as possible. Of course, some manufacturers make rubber compositions that are more resistant than others; but it is hard to determine who can be relied upon most, as the tire companies have changed their mixtures a great deal in order to get the best, so one year one may be ahead and another year it may be a different company. With tires it is not only the rubber, but the character of the canvas fabric, its amount, method of application and union with the rubber strata that are important. But one of the main points in regard to the probable wear is ascertained by securing strips of the rubber compound in question about six inches long and about one-eighth inch square section. One notes about how far an inch measured on the rubber may be stretched. It should easily stretch to three inches. When released it is seen how near to the original marks of the inch length the sample finally shows. A good sample should not show any permanent elongation.

Any one can determine the amount of mineral matter in rubber by ashing a weighed sample until all the carbon is consumed and the ash is light in color and then weighing this residue on an accurate balance. When rubber is burned and the flame quickly blown out the residue is very sticky, and the paste makes a good cement for some purposes, especially if mixed with powdered mineral matter of some kind.

Cements for different purposes can be made from chemicals purchasable at any drug store. A strong water- and oil-proof cement is made by mixing litharge and glycerin to a stiff paste. It sets in a few hours to a hard substance. Sorel's cement is valuable. It is made by mixing a strong solution of magnesium oxychloride with magnesia (burned magnesia) to a stiff paste. A paste made by mixing concentrated phosphoric acid and zinc oxide sets in a minute or two to form zinc phosphate. This is used by dentists for filling teeth. Melted gutta percha is also a good cement and much used by dentists. Gutta percha is chemically much like rubber, but it is stiffer when cold and softer when hot. This makes it useful for a cement and as an insulation and protective coating for transatlantic cables. Gum chicle, used for chewing-gum, and balata, used for impregnating belting for power purposes, are also of the rubber family.

CHAPTER XXI

SILICOUS SUBSTANCES AND GLASS

Silica is the most widely occurring mineral substance in the earth's crust. Of course, we do not know what is very deep in the interior,[1] although astronomers and geologists have made clever attempts to find out, such as measuring the mutual attraction of the earth and suspended bodies. Lava flows are very silicious, which suggests the composition well below the surface.

Silica (SiO_2) itelf is a chemical union of the metal silicon (Si) and oxygen. Silicon is not often met with, and was not produced in a commercial way until a few years ago, when an electrochemist at Niagara Falls, C. J. Tone, built a practical electric furnace for the purpose by which he produces some tons a day of the metal. Silicon is used in steel making to absorb traces of oxygen and thus render the steel denser and tougher. In absorbing this oxygen the silicon reverts to silica, so silicon is not accumulating in its divorced condition.

Silica has never been much used by itself, but recently tubes, crucibles, evaporating dishes, etc., have been made for chemical laboratories. They are proving very useful, as they stand high temperatures and expand so little by heat that they can be heated to redness and then plunged at once into cold water without cracking at all. Every one knows what would happen to glass under such circumstances. It seems probable to the writer that such ware may be found useful in the home for cooking purposes, as nothing injurious would come off from them in use. Sudden cooling would not hurt them, but they are about as brittle as glass, which they resemble closely in appearance, and they could not, therefore, be safely dropped on the floor. Pressed-steel and cast-iron vessels are enamelled with silicious compositions, which contain borax and other fluxes to make the glaze melt at low enough temperatures to be applied cheaply. There are enamels made in this country which approximate the properties of silica, are not very attackable by acids or other corrosive liquids, and do not crack off easily by expansion. They are, however, relatively high-priced and are used for dairy, food, and chemical purposes.

---

[1] See p. 144.

We must go back to rocks now and consider silica free, as quartz, and in grains, as sand, and also silica[2] in combination with basic substances, such as iron oxide,

---

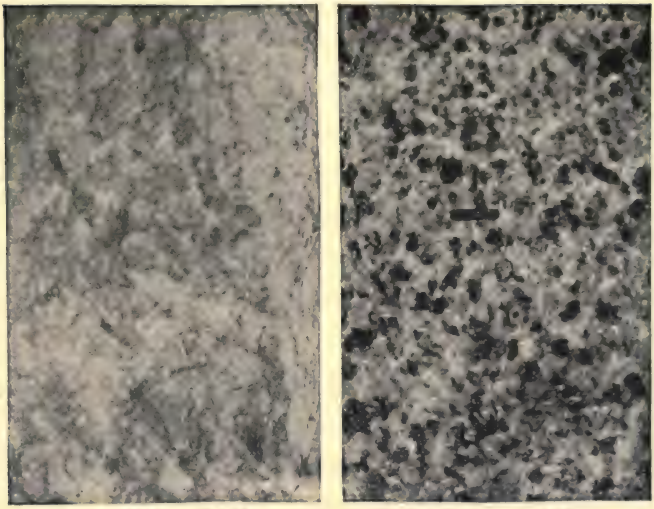
[2]
$$\begin{array}{c}\text{Silica }(SiO_2)\\ \text{(acid substance)}\end{array}\quad \begin{array}{c}\text{combines}\\ \text{with}\end{array}\left\{\begin{array}{l}\text{Lead oxide, }PbO\\ \text{Alumina, }Al_2O_3\\ \text{Iron oxides, }Fe_2O_3\text{ or }FeO\\ \text{Lime, }CaO\\ \text{Barium oxide, }BaO\\ \text{Magnesia, }MgO\\ \text{Sodium oxide, }Na_2O\\ \text{Potassium oxide, }K_2O\end{array}\right\}\text{to form}\left\{\begin{array}{c}\text{Silicates}\\ \text{of}\\ \text{these}\\ \text{bases}\end{array}\right.$$
$$\text{(basic substances)}$$

alumina (aluminum oxide), lime (calcium oxide), magnesia (magnesium oxide).

Rocks are more practical for consideration to most of us than ores of valuable metals, as the former abound everywhere, while the latter are found only in spots and are dug out as quickly as possible, even if tunnels have to be driven to find them, and sent to the smelter to be reduced with heat and coke to metals, so most of us do not see them in their natural forms. Rocks produce soil, give contour to the earth's surface, and are useful for building houses and roads. Rocks are known from their earlier origin, or later origin, as *igneous, sedimentary,* and *metamorphic.*

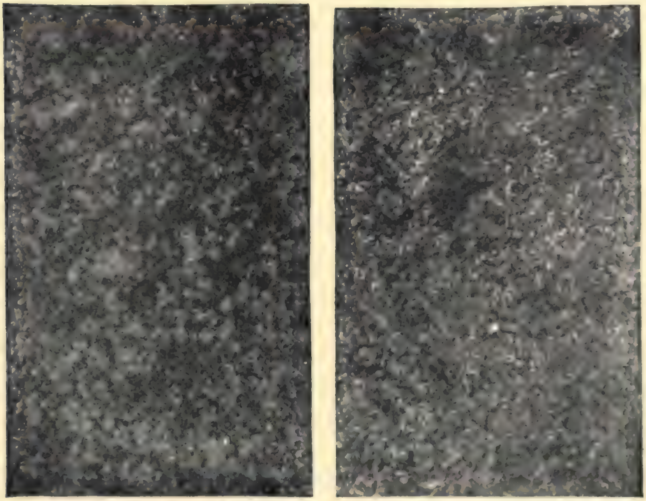
Igneous rocks have cooled from a state of fusion in the location substantially where found. In cooling, the ingredients separate (except in the case of obsidian or natural glass) and crystallize. As silica is apt to be in excess of the amount necessary to form silicates with all the bases, it crystallizes in more or less well-defined forms throughout the mass. When the crystallization is well defined it is called quartz. Other minerals separate out from the masses, according to their different compositions, in crystals. Granite is the best example of these igneous rocks. There are in the mass several minerals collectively known as feldspar, one variety of which is a complex silicate of potassium and aluminum; this generally is slightly pinkish and gives

PLATE XXIII.



A. Anorthosite, all feldspar.

B. Syenite, mostly feldspar.



C. Diorite, some feldspar.

D. Peridotite, no feldspar.

Pirsson's Rocks and Rock Minerals: Wiley.

CONTRAST OF FELDSPATHIC AND FERROMAGNESIAN ROCKS.

most of the characteristic color to the granite; there are large quantities of crystals of silica which are glassy; and then, as a rule, crystals of a black mineral called hornblende, which is a complex silicate of calcium, magnesium, and iron. These substances were all disseminated when hot, but, as the mass cooled, separation took place according to the chemical affinities, and the result was granite.

Sedimentary rocks are those that have formed after their elements have been worn away from igneous rocks and, because of pressure or cementing washes, have re-formed rock, such as slate and sandstone. The former is made up of clay compacted by pressure, and the latter from sand by percolation of silicious waters or great pressure and some cementing substance. Sediments are carried by wind and water, but they are nearly all arranged and classified by water, which carries the coarse particles only short distances, the finer particles further and deposits them together, and the very finest grades of clay are carried great distances and form very unctuous clay beds; some of these have under pressure hardened to slate, or mixed with lime have formed more or less argillaceous limestones. Rocks containing the proper proportions of lime, aluminum, and silica are burned to expel carbon dioxide and water, and when powdered make Portland cement. A great deal of limestone is sedimentary, as is referred to in Chapter XI. It has been formed from the calcareous skeletons of marine animals and has made chalk or, if it had been heated under pressure, crystallized limestone. Silicious skeletons of microscopically small diatoms have been carried by water currents and deposited in strata, sometimes of great extent. This fine silica is called infusorial or diatomaceous earth and is used for insulation. *Metamorphic* rocks are those that since cooling have been changed by some agency, such as the collection of partly weathered rock particles, into fresh rock aggregates by means of streams of igneous matter, or heat and pressure, etc. It was always interesting to the writer to see stratified rocks in railroad cuts; to realize how they were distorted at one time by unequal pressure from below, when the earth's crust was thinner; to note how they were worn away unequally at the surface, where evidence shows, from the direction of the strata, that land miles higher than now exists was worn away and carried into the sea. These agencies of change have always been at work and will doubtless continue, although it is probable that the rate of change is much slower now than it once was; for instance, at a time when the water on the earth's surface was so heated from below that, like a vast hot-water heating system, it provided a tropical atmosphere even at the poles. At such a time, when there were also larger amounts of carbon-dioxide gas, which has since been deposited as coal, the attack on mineral aggregates, such as limestone and feldspar, by the conjoint action of heat, water vapor, and carbon dioxide was greatest, and as the rock obtruded it crumbled rapidly in comparison with the present rate.

Stone for building should be such as will stand the weather reasonably well. Some rock is nearly all silica, known as quartzite, and is practically everlasting. The writer was fortunate in getting this stone for his house, but it was not a beautiful stone by itself and so was covered up with cement plaster. Granite is about the most durable building stone we have, although it does not resist fire well, due to traces of water inclosed in the silica, which expands, and then the several minerals separate. After this probably come micaceous rocks of uniform dense structure. Some schists have not had sufficient metamorphic action to be enduring. Dense crystalline marbles are structurally firm, although carbon dioxide may wear away the surfaces very slowly, and if the spaces between crystals are great enough the decay is more rapid. The stones used sometimes for building which have been conspicuous for weathering, besides mica schist, are serpentine (a hydrated silicate of magnesium), sandstones (particularly brown sandstones which contain iron), and I might add bricks that are not hard burned.

Road stones must be as hard as possible, even if the road is made with an asphaltic or pitch binder. Crushed limestone is frequently used for this purpose, because of its cheapness in certain localities. For little-used private roads it is probably the best material, for it becomes well cemented together by the rain, especially if there be a proportion of "fines." Oyster-shell roads, that are sometimes met with near the coast, are well known for their firm, smooth surfaces. For public roads, however, limestone does not do at all, as it is promptly crushed to powder by traffic, even if there be a binder. *Trap rock* is most in demand, as it is very hard. On hill and mountain slopes the rocks that stand out from the soil and have survived the general decay are usually trap rock, which is a kind of basalt, of igneous origin.

The rocks that are most found can be analyzed sufficiently for identification by any one. A blade of a pocket-knife will scratch nearly all but silica. Of course, corundum and garnet are too hard to scratch, but they are not abundant. Limestones will effervesce with acid (vinegar). Feldspar is softer than silica (may be scratched with knife-blade), is generally pinkish, although sometimes green or grayish. It is not as vitreous as silica. Mica is known by its scales. Hornblende is hard and coal black.

Glass occurs in nature as a volcanic effusion known as obsidian, but man prefers to make his own rather than use nature's.

Glass making is an interesting line of manufacture, and spectacular as well, for the handling of large ladles of molten glass is very impressive, and the moulding of masses for plate-glass, the blowing of large cylinders for window-glass by mechanical means, and the blowing of smaller bubbles by human lung-power, are sights to be remembered. One of the writer's children at the age of three asked him, in a "brogue" characteristic of that time of life, what glass was made of. He was told that it was made of sand. This was not enough, so he asked what made the sand " 'tick together," which was a thoughtful observation. They use very pure white silica sand and make it stick together by heating it with some form of soda, such as sodium sulphate or soda ash, and pure lime. This makes a compound silicate of soda and lime, and this general composition is used for most purposes, such as windows, bottles, and ordinary moulded articles. For cheap bottle glass iron-containing sand is used, which produces a greenish color. This is neutralized in some cases with manganese. In old houses one often sees purple panes of glass in the windows. These are highly prized by the old families. This glass had manganese added to neutralize the color due to iron, and by the action of light the purple color has probably been formed.

In Germany glass was made originally from wood ashes, which are rich in potash. They still make potash glass which is called Bohemian glass, and is more infusible than other glass and used for combustion tubes in the laboratory. *Jena glass,* used for thermometers and chemical ware, contains borax and some alumina. The most beautiful glass is potash-lead silicate, or flint glass. It has a high index of refraction and consequently has a more brilliant appearance, especially when cut. This composition is used for so-called "paste" diamonds and for optical purposes. It is not as insoluble in water as other glasses. Some glasses are lime-potash-soda silicates, and are used as enamels for buttons, pin-heads, and cheap jewelry.

Iron—green
Cobalt—blue
Antimony—yellow
Uranium—opalescent yellow
Sulphur—black
Gold—ruby-red
Manganese dioxide—violet-red
Phosphate or cryolite—white.

The colors in glass are due to metallic oxides. By the addition of carefully selected oxides glass is made that will shut out certain rays of light without affecting others. Sir William Crookes has invented a special glass, for instance, that will shut out 98 per cent. of heat rays, and another that eliminates the ultra-violet rays. Glass is toughened by plunging it into oil while hot.

Clay ware, which includes earthen-ware, chinaware, and porcelain, differs from glass in that a natural silicate is used which does not fuse in the manufacture, although it softens more or less.

Earthen-ware is made from clay which does not burn very white. As a rule, it is cheap clay and the finished article has no claim for either beauty or strength. It is made in a single burning and the glaze is due to saline matter on the surface. This salt is thrown into the kiln and volatilizes first, permeates the kiln and then unites with the biscuit-ware, forming a more or less dense coating.

Porcelain is made from white kaolin or clay, which is a silicate of aluminum and free from iron. Some feldspar is mixed with the clay to make it fusible enough to close the pores, and silica to reduce the shrinkage on firing. When the ware comes out of the kilns it is white, dull, and somewhat porous. This is called biscuit-ware, and it is washed with a fusible glaze ground up in water and returned to the kiln. The ware then becomes lustrous when finished.

The chemistry of all porcelain work is largely the same, but the excellence of the workmanship in moulding and character of the clay, the slight differences in the composition of the glazes, and the skill of the decorators determine the character of the ware. If porcelain wares were piled one upon another in kilns the glazes would cement them together. The glaze is removed from the under rim and they are set in fire-clay receptacles called saggers. In cheap ware there are small three-pointed spiders that separate the plates and touch the bottom and top of each in three places. At these points the glaze is spoiled.

An important line of manufacture has grown up in recent years in the making of *glazed building tiles.* This seems like a nearly ideal building material if the glaze is insoluble, as there are no appreciable cracks or pores for the moisture to get in and then to freeze and break down the structure, as happens in much of the brick used. With reference to *brick,* the only kind of brick that would seem entirely satisfactory for building is the very high-temperature brick called "down draught" or that made in pottery kilns.

A few words might be said about *precious stones.* The chemist has finally succeeded in making practically all of them,—not cheap imitations, but the real articles. Diamonds are made artificially that are just the same in composition—namely, pure carbon—as the natural ones. The great French chemist, Moissan, as is well known, has made small diamonds by placing some sugar carbon in a sealed iron container and then plunging it into a bath of molten iron. Carbide of iron is formed by the union of carbon and iron. The outside of the iron is then chilled with water, which causes a contraction, and this subjects the interior to great pressure. As the carbon is thrown out of solution in the iron on cooling at high pressure, very small diamonds are formed, which are recovered by dissolving away the iron with acid. Rubies and sapphires are crystallized alumina colored with metallic oxides. They have been made in the laboratory by fusing alumina with traces of oxides in the heat of a blow-pipe in an ingenious way devised by Verneuil. The flame of the blow-pipe carries finely powdered alumina with coloring oxides, such as chromium, and builds up drops of crystalline material, which constitute the gems. These stones are the same in composition, appearance, and properties as those naturally occurring. The emerald is silicate of beryllium, or beryl, with a trace of chromium. Topaz is a silicate of aluminum and is harder than quartz. It is generally yellow to brownish-yellow in color.

Portland cement, known in the time of ancient Rome, has been rediscovered in comparatively recent times. It has become, after wood, probably the most important building material we have. Building with cement is fire-proof, weather-proof, and, when reinforced with steel rods, of enduring character. It is normally not quite water-proof, but by putting in mixtures containing fish oil, etc., in proper amount, it is made water-proof.

Portland cement is made by heating to a white heat sand, clay, and limestone,—calcareous clay, or argillaceous limestones, or any mixtures of silica, alumina, and lime that on burning would give a resultant mixture that contains, approximately, lime 65 per cent., alumina 25 per cent., and silica 10 per cent.; a little iron may replace alumina. The clinker so formed must be ground to impalpable fineness. Magnesium compounds and sulphates in very appreciable amounts are undesirable constituents of Portland cement. Cement coatings seem to protect steel from corrosion except where stray electric currents may cause corrosion in damp places. In the setting of Portland cement several lime compounds are formed, such as calcium silicates and calcium aluminates, which in crystallizing with water, in the same way that plaster of Paris does, cause a setting, or form a monolith, where a form is prepared for it, with the sand and stone used as diluents.

The value of cement is determined by making briquettes, with sand, that have a square inch cross section in the narrowest part. After the briquette has been properly set with water it is put under a pulling strain and the number of pounds taken to break it are noted.

Asbestos is silicate of magnesium which, according to variety, may also contain associated silicate of iron, alumina, or lime. It is valuable for its fibrous structure. It is chemically related to other well-known minerals, such as talc, serpentine, and meerschaum, which are simple magnesium silicates, and hornblende is a lime-magnesia silicate containing iron.

Asbestos as loose packing or corrugated sheets is a good heat insulator and has quite a reputation for withstanding the intense heat of direct fire. Flame applied directly does not melt or consume it, but it takes away its life by rendering it quite brittle. For curtains and fabrics, such as automobile brake linings, where strength is required, it is woven with copper or brass wire. Brake linings are also impregnated with some tough paint or varnish such as montan wax. Asbestos for insulation has given ground a little of late to well-packed infusorial earth, diatomaceous earth, or (German) Kieselguhr.

CHAPTER XXII

A FEW IMPORTANT DEFINITIONS

Adsorption is the abstraction and retention of matter from solution by insoluble substances, generally as powders in suspension. It seems to be a quasi-chemical attraction without chemical change. It is a physical change. The composition of the matter in solution and that of the powder largely determines the phenomena, although the structure of the powder is a vital element. Adsorption differs from absorption in signifying a drawing *to* rather than a drawing *in*. Examples of adsorption are the clarification and decolorization of oils with fullers' earth; the removal of oily turbidity from aqueous liquids with magnesia; the removal of dye from aqueous solution with fine silica or aluminum hydroxide, etc.

Catalytic agents are substances that induce chemical changes without being themselves altered in composition. Examples of this action are: A platinum sponge acting to cause ignition of gas in the presence of air; finely divided nickel acting to cause the hydrogenation of liquid fats; iron oxide causing the union, under heat and pressure, of hydrogen and nitrogen to form ammonia.

Enzyme action is really catalytic action, as the enzyme simply induces the chemical change. Examples of enzyme action are the action of diastase in forming sugars from the starch in malt, chlorophyll in inducing the union of carbon dioxide and water to make formaldehyde as a step in making carbohydrates, and the action of the digestive juices. They are organic catalysts.

Colloid chemistry deals with particles of matter in such fine suspension in liquids that they approach a true solution. These particles cannot of themselves be seen with the most powerful microscope, but by the reflection of light from these particles their suspension can be noted by a microscope fitted up for this purpose, called the ultra microscope. The fine particles of *purple of Cassius* and gelatin and agar-agar jellies are examples of colloids. The present knowledge as to colloids is very helpful in explaining certain chemical phenomena.

Eutectic alloys are those solid solutions of one metal in another that have the lowest melting point. This melting point is lower than that of either constituent. This subject is of great importance in judging the qualities of steel under the microscope.

Petrography is the study of rocks or stones; especially applied in judging their quality for building and other purposes. Polished surfaces are examined under magnification, somewhat as is done on a section of steel and alloys.

Radio-activity is the name given to the property of certain substances of giving off radiant energy. These radiations ionize[1] air, or cause it to conduct electricity and to affect photographic plates, and make phosphorescent substances luminous, although the rays themselves are not visible.

Synthetic chemistry is the branch of chemistry that deals with the building up of complex substances from simpler ones, such as the making of dye colors from simpler substances.

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[1] Dissociates to the atomic condition.

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